TEACHER GUIDE

MEASURING RELATIVE HUMIDITY AND DEW POINT

MATERIALS PER GROUP:

- Metal can
- Small rubber band
- Cotton wick
- Rubber cap
- Ice
- Plastic pipette
- Screw
- Screwdriver
- Plastic or wooden handle
- Water, room temperature
- 3 plastic-backed, nonmercury thermometers
- 3 colored markers (optional)
- Ruler (optional)

TOTAL DURATION:

120 min. pre-lab prep time; 40-50 min. class time

LESSON OBJECTIVES:

Students will be able to:

1. Construct a sling psychrometer.
2. Determine direct dew point.
3. Use sling psychrometer to determine dew point and relative humidity.
4. Calculate dew point and relative humidity.
5. Read reference tables.

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LESSON OVERVIEW:

The concepts of relative humidity and dew point are both part of the field of psychrometry, or the study of the principles of moisture in the air. The issue of moisture in the air affects all of us on a daily basis in the form of weather. Whether you live in an arid desert region or a lush tropical region, you experience the effects of dry air (atmospheric air comprised of nitrogen and oxygen) and water vapor in the form of humidity, rain, and frost.

ESSENTIAL QUESTION:

How are relative humidity and dew point measured?

TOPICAL ESSENTIAL QUESTION:

What effect does temperature have on relative humidity and dew point?

SAFETY PRECAUTIONS:

- Check that the thermometers are securely attached to the plastic handles before allowing students to swing them. (Teacher may assemble the psychrometers prior to students using.)
- Handle thermometers carefully to avoid dropping.
- Keep control of the psychrometers at all times.
- Always wear eye protection.

STANDARDS

Middle School
MS-PS3-4
Students who demonstrate understanding can:
Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass and the change in the average kinetic energy of the particles as measured by the temperature of a sample.

MS-ESS2-4
Students who demonstrate understanding can:
Develop a model to describe the cycling of water through the Earth's systems driven by energy from the sun and the forces of gravity.

Science and Engineering Practices:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating and communicating evidence

Crosscutting Concepts:

1. Patterns
2. Cause and Effect: Mechanisms and explanations
3. Scale, Proportion and Quantity
4. Systems and System Models
5. Energy and Matter: Flows, cycles and conservation
6. Structure and Function
7. Stability and Change

KEY VOCABULARY:

Psychrometry
Dew point
Sling psychrometer
Frost point
Relative humidity

LAB BACKGROUND INFORMATION:

NOTE: This is background information for the teacher to assist in facilitating learning and will be explained to the students after the Explore section.

The concepts of relative humidity and dew point are both part of the field of **psychrometry**, or the study of the principles of moisture in the air. The issue of moisture in the air affects all of us on a daily basis in the form of weather. Whether you live in an arid desert region or a lush tropical region, you experience the effects of dry air (atmospheric air comprised of nitrogen and oxygen) and water vapor in the form of humidity, rain, and frost.

Psychrometry is a very important science to agriculture. It is used to create and control micro-environments in livestock facilities, greenhouses and grain bins. Understanding the relationship between water vapor and temperature allows producers to create environments to provide for animal comfort, maximize production, prevent loss and increase profits.

Two underlying concepts are important to the study of psychrometry: temperature and state of matter. As we learned in the water cycle, water exists on Earth in three forms: solid, liquid and gas (vapor). Temperature has an effect on the state water exists in as it influences the speed of the molecules. Water moves from the liquid to the vapor state when it is exposed to high levels of heat (from the sun), causing the molecules to increase their speed and move farther apart from one another and rise into the air filling the spaces between the gas molecules. When temperatures are high, the atmosphere has more energy and will hold more water vapor than when it is cold because the molecules move faster and have more space available. The amount of water vapor the atmosphere will hold is called humidity. On hot days, the air feels sticky and heavy – this is humidity. Geographical regions with more greenery or near large bodies of water have higher humidity than areas like the desert where little water is available for evaporation.

Meteorologists, or weather scientists, measure the humidity in the air in terms of **relative humidity**. This is the percentage of moisture the air is holding compared to the maximum it can hold at a given temperature. It is expressed as a percentage. Relative humidity is important because it influences weather events like cloud formation and precipitation. Clouds form when the air cools enough to cause water vapor molecules to collide and stick together or change phase and condense. The more humidity in the air, the more clouds will form. For precipitation to occur, the air has to reach 100 percent relative humidity, meaning the air is saturated and cannot hold any more water. The water is released into the atmosphere as rain, snow, sleet or hail.

One way to measure relative humidity is to use a **sling psychrometer**, a device made of two thermometers, One thermometer measures the temperature of the dry air (dry-bulb thermometer) and the other measures the temperature of the air as evaporation occurs (wet-bulb thermometer).

The sling psychrometer can also be used to measure **dew point**. Dew point is the temperature at which air must be cooled for saturation to occur (dew to form). You may be familiar with this concept if you've ever had a cold glass of lemonade on a hot summer day. You probably noticed the glass starts to "sweat." Cold air cannot hold as much moisture as warm air. The cold liquid inside the glass cools the air temperature around it, causing the water vapor in the air to condense on the sides of the glass, returning it to the liquid state. The same concept applies at night when the dew forms on the grass. The air temperature falls after the sun sets, and the cooler air near the ground loses its capacity to hold the water vapor, causing condensation on the grass blades or objects on the ground. These are both examples of the dew point concept – when the temperature around the object is cooled enough to form liquid water. You may also be familiar with the concept during the winter when frost forms on the grass and cars. When the dew point is below freezing (32° F), it is commonly referred to as the **frost point**.

The difference between the air temperature and the dew point indicates whether the relative humidity is high or low. When the air temperature and the dew point are dramatically different, the relative humidity is low. When the air temperature and the dew point are close to the same value, the relative humidity is high. *If the two numbers are equal, then relative humidity is at 100 percent.*

ENGAGE:

Show pictures of a frost-covered car and a can of soda with condensation. What do these pictures have in common? Show pictures of a dairy barn, a greenhouse and a grain silo. What do these pictures have in common? What do all six of the pictures have in common?

Discuss what psychrometry is, and relate the phenomenon of moisture in the air causing humidity, frost and dew. In agricultural settings, producers create micro-environments in which they control temperature and humidity to provide a comfortable environment for animals, the right conditions for plants at various stages of growth, or create drying conditions in grain storage.

EXPLORE:

In this activity, you will learn to construct and use a sling psychrometer, and utilize different methods to determine relative humidity and dew point levels of air.

Note to the teacher: In this lab, temperature measurements are recorded in Fahrenheit because it is the official weather unit in the United States, and students are more able to relate to it.

PROCEDURE:

Activity 1: Measuring Condensation Point

1. Fill the metal can approximately one-half full with room-temperature water.
2. Place a thermometer in the water and record the initial temperature (°F) in the data table.
3. Slowly add ice to the water and swirl the can gently. As soon as moisture is felt on the outside of the can, note the temperature. This is the dew point temperature. Record in Data Table 1.

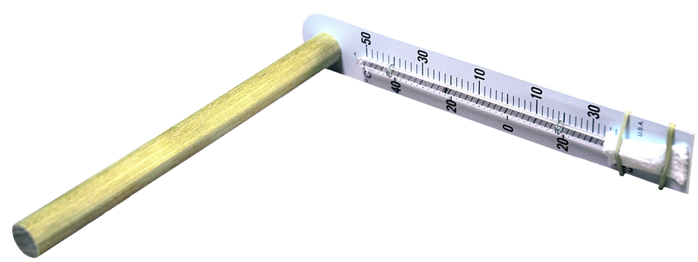
NOTE: If large water droplets form on the outside of the can before the final temperature is recorded in step 3, the recorded final temperature will not be accurate. If this occurs, empty and dry the can, and repeat the procedure after the can reaches room temperature.

Data Table 1: Measuring Condensation *If time permits, do at all three locations. If time is a factor, do inside only*

	Inside	Outside in sun	Outside in shade
Initial Temperature (F)			
Condensation Point Temperature (F)			

Activity 2: Construct the Sling Psychrometer

1. To make the wet-bulb thermometer, take a ½" piece of cotton wick and cover the bulb of one thermometer.
2. Attach the wet-bulb thermometer to a dry-air thermometer by placing the two plastic backs together and wrapping a small rubber band close to the bulb ends to hold them together.
3. Put the screw through the aligned holes of the thermometers.
4. Twist the screw carefully into the end of the plastic handle (with the pre-drilled hole in it) until at least half of the screw is inside the handle.



In the image above, note that that the two thermometers are back to back: dry bulb on top of wet bulb.

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Activity 3: Sling Psychrometer Measurement

Perform the following steps in three locations (inside a building, outside in the shade and outside in the sun).

1. Using the sling psychrometer you assembled, measure the air temperature using the dry-bulb thermometer. Record this value in degrees Fahrenheit in Data Table 2.
2. Use a pipette and place 2 drops of water on the gauze of the wet-bulb thermometer.
3. Hold the plastic handle in your hand and slowly rotate the thermometers around the screw. The spinning motion will accelerate the evaporation rate of the water.
4. Spin the thermometers on the sling psychrometer for 30 seconds.
5. Immediately check the temperature of the wet-bulb thermometer and record in Data Table 2.
6. Subtract the wet-bulb temperature from the dry-bulb temperature (assuming dry is higher than wet). Record in Data Table 2.
7. Use Reference Table 2 to find the relative humidity by finding the dry bulb temperature in the first column and the difference between dry and wet bulb temperature in the first row. The relative humidity will be the number where the two cross. Record your answer in Data Table 2.

Data Table 2: Sling Psychrometer Measurements

	Inside	Outside in sun	Outside in shade
Dry-bulb Temperature (F)			
Wet-bulb Temperature (F)			
Difference between Dry and Wet Temperatures (F)			
Relative Humidity (%)			

Reference Table 2: Relative Humidity in Percentage (%)

	Differences Between Dry Bulb and Wet Bulb (°F)														
Dry-bulb Temp (°F)	**1°**	**2°**	**3°**	**4°**	**5°**	**6°**	**7°**	**8°**	**9°**	**10°**	**11°**	**12°**	**13°**	**14°**	**15°**
32	90	79	70	60	50	40	31	22	13	4	x	x	x	x	x
34	91	81	72	62	53	44	35	26	18	9	1	x	x	x	x
36	91	82	74	65	56	48	39	31	22	14	6	x	x	x	x
38	92	83	75	67	59	51	43	35	27	19	11	4	x	x	x
40	92	84	76	68	61	53	46	38	31	23	16	9	2	x	x

Reference Table 2: Relative Humidity in Percentage (%)

	Differences Between Dry Bulb and Wet Bulb (°F)														
Dry-bulb Temp (°F)	**1°**	**2°**	**3°**	**4°**	**5°**	**6°**	**7°**	**8°**	**9°**	**10°**	**11°**	**12°**	**13°**	**14°**	**15°**
42	90	79	70	60	50	40	31	22	13	4	x	x	x	x	x
44	91	81	72	62	53	44	35	26	18	9	1	x	x	x	x
46	91	82	74	65	56	48	39	31	22	14	6	x	x	x	x
48	92	83	75	67	59	51	43	35	27	19	11	4	x	x	x
50	93	87	91	74	68	62	56	50	45	39	33	28	22	17	12
52	94	87	91	75	69	63	58	52	47	41	36	31	25	20	15
54	94	88	82	76	70	65	59	54	49	43	38	33	28	23	20
56	94	88	83	77	71	66	61	56	51	45	40	36	31	26	22
58	94	89	83	78	72	67	62	57	52	47	42	38	33	29	24
60	94	89	84	78	73	68	63	58	54	49	44	40	35	34	27
62	95	89	84	79	74	69	64	60	55	51	46	42	38	34	29
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32
68	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38
74	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39
76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44

Reference Table 2: Relative Humidity in Percentage (%)

Differences Between Dry Bulb and Wet Bulb (°F)															
Dry-bulb Temp (°F)	**1°**	**2°**	**3°**	**4°**	**5°**	**6°**	**7°**	**8°**	**9°**	**10°**	**11°**	**12°**	**13°**	**14°**	**15°**
82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45
84	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46
86	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49
92	96	90	89	85	82	78	75	72	68	65	62	59	56	53	50
94	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51

Activity 4: Construct the Sling Psychrometer

In Activity 1, students conducted a direct measure of condensation point, also known as dew point. Now students will use the Psychrometric Chart to calculate the dew point.

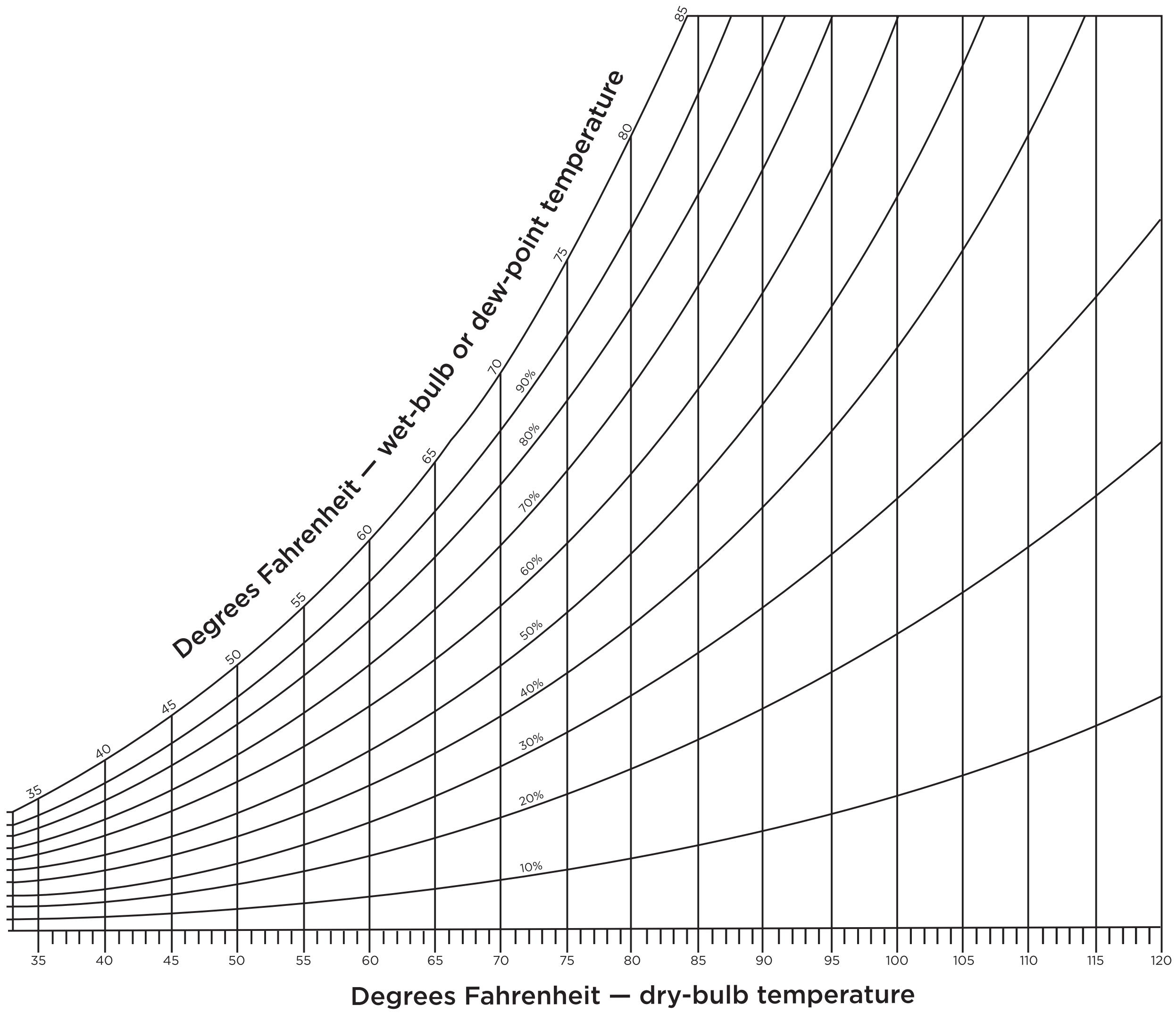
Using the psychrometric chart below, students will use the measurements taken in parts 2 and 3 to find the dew point temperature. It may be helpful to use different colors for the three temperatures (inside, outside in sun, outside in shade).

1. On the psychrometric chart, dry-bulb temperature is located on the x-axis. Find the dry-bulb temperature for inside, and draw a line straight up and down on the chart.
2. On the psychrometric chart, relative humidity is represented by the curved lines starting on the left side. Find the relative humidity for inside, and draw a curved line on the chart.
3. To determine dew point using the chart, find where the dry-bulb temperature line and the relative humidity line cross. From this point, draw a horizontal line straight across to the outermost left curve. This represents the dew-point temperature. Record in Data Table 3.
4. Repeat steps 1-3 for outside sun and outside shade.

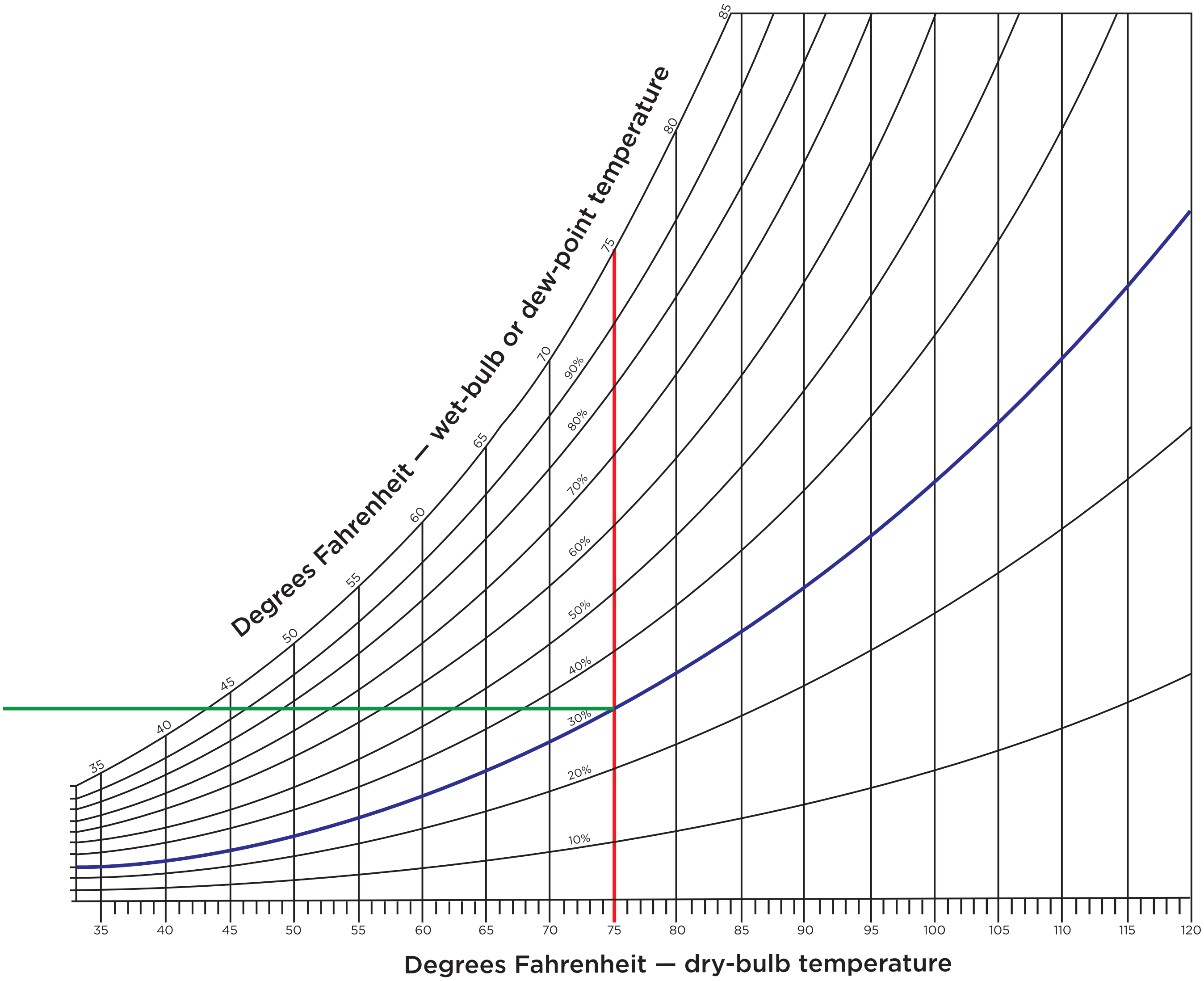
Data Table 3: Dew Point Measurements

	Inside	**Outside in sun**	**Outside in shade**
Dew Point Temperature (F)			

Psychrometric Chart



Example of how to complete psychrometric chart:



If dry bulb temperature is 75°F (red line) and relative humidity is 30% (blue line), then the calculated dew point is 43°F (where the green line crosses the outer curved line).

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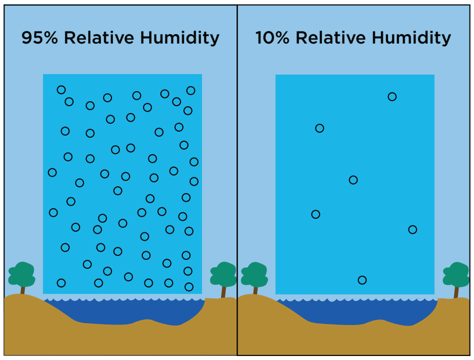
EXPLAIN: (SEE LAB BACKGROUND)

The Lab Background Information from the Teacher Guide is repeated in the Explain section of the Student Guide. Below is additional information to help aid in the explanation.

The concepts of **relative humidity** and **dew point** are often difficult for students, and even adults, to understand. These terms are often heard during weather reports on the evening news, but few individuals understand what they actually mean. It is first important to remember air temperature is the most important factor when discussing relative humidity and dew point. **Cold air doesn't hold as much moisture as warm air.** As the air temperature increases, it can hold more moisture because the air molecules are moving faster and spread farther apart, creating more room for evaporated moisture. Additionally, as temperatures increase, evaporation from plants and water bodies increases, adding more water into the atmosphere.



Most people use relative humidity as an indicator of the level of humidity, but dew point is actually a better measure. ***Dew point is related to the quantity (amount) of moisture in the air. This is also called the condensation point – the temperature that a gas (water vapor) becomes a liquid (water).*** As illustrated by the image to the right, the higher the dew point, the more uncomfortable it is. Many people say it isn't the heat that bothers them, it's the humidity. This is very true. When the dew point is high, it means there is already a lot of moisture in the air and sweat doesn't evaporate as easily, resulting in your body's decreased ability to cool itself. This is called **evaporative cooling**. This concept is also one of the foundations of transpiration and water movement (water potential) as well as the formation of the Earth's biomes.

Dewpoint	Perception
52 & lower	Comforable
53-56	Slightly Noticeable
57-59	Quite Noticeable
60-63	Sticky
64-69	Uncomfortable
70+	Intolerable

For further information on these concepts, check out the video by Fox Meteorologist Vince Condella from Milwaukee, Wisconsin. https://www.youtube.com/watch?v=S8W-xl4mcJ8

As an optional demonstration to aid in student understanding, the teacher can demonstrate the concepts of relative humidity and air temperature with beakers.

MATERIALS:

100 mL beaker labeled 40°F, 250 mL beaker labeled 50°F, 600 mL beaker labeled 80°F, and a large container of water.

Explain that relative humidity is the amount of water the air is holding relative to how much it can possibly hold. Then illustrate this concept by performing the demonstration:

1. Pour 50 mL of water into the 100 mL beaker. How full is the beaker? Half full or 50%. This represents 50% relative humidity at 40°F.

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2. Now the temperature increases by 10 degrees. Pour 50 mL from the 100 mL beaker into the 250 mL beaker. What is the relative humidity at 50°F? The beaker is only 20% full, so the relative humidity is 20%. (Note the change from 50% to 20% produces a greater capacity to hold water.)
3. As temperatures increase, water vapor is added to the air from evaporation from plants and open bodies of water. This will affect the relative humidity. So continuing the example, pour an extra 100 mL of water into the 250 mL beaker at 50° F. This amount represents additional evaporation from the environment. What is the relative humidity now? (150 mL/250 mL) 60%
4. To finish the demonstration, let's raise the temperature 30 degrees. Pour 150 mL from the 250 mL beaker into the 600 mL beaker and add an additional 300 mL of water to represent increased evaporation. What is the relative humidity now? (450mL/600mL) 75%

ELABORATE:

Optional Extension Activities

1. Have students compare their calculated values to values reported by a local weather station or the National Weather Service (http://weather.gov). Discuss the reasons that the measurements may be different.
2. Have students collect data over a period of time and graph their data to show trends over time.
3. The height of cumulus cloud bases can be calculated using the dew point temperature and the surface air temperature.

   Height of cloud base (in feet) = 222 [temperature of air (F) - dew point temperature (F)]

EVALUATE:

1. Explain, in your own words, why dew point may be different on different days.
Answers will vary, but the definition is the temperature of the air at which saturation occurs.

2. Why might a gardener want to watch the weather when the temperature at night is forecast to be low?
If the night time temperatures are nearing freezing, they would want to protect their plants from frost, which
causes damage to plants which can lead to death.

3. What is relative humidity?
The amount of moisture in the air compared to the maximum amount of moisture the air can hold

4. What effect does temperature have on relative humidity?
The warmer the air, the more moisture it can hold, making the relative humidity higher. Cooler air cannot hold as much moisture so the relative humidity would be lower.

5. Why is relative humidity and dew point important to agriculturalists?
It is necessary for livestock producers to create comfortable environments for their animals; for crop farmers to know when to plant and harvest; for horticulturalists to create environments in their greenhouses to allow their plants to thrive.

6. Which factor influences relative humidity and dew point the most?
Air temperature

7. Using your knowledge of dew point and relative humidity, construct an explanation for why frost forms on a car overnight when temperatures are low and why condensation forms on the outside of a glass of ice water. Be sure to provide evidence from your investigation and/or personal experience in your explanation.
Answers will vary, but students should relate the ideas of dew point and relative humidity to the amount of water vapor present in the atmosphere, and how when the temperature drops to a specific temperature, water vapor will condense on cooler surfaces. If the temperature is above freezing, dew forms; if the outside temperature is below freezing, then frost will form.

Noble Academy would like to thank the following people for their contributions to this lesson:
- Quentin Biddy
- Susie Edens
- Kay Gamble
- Janie Herriott
- Fiona McAlister

STUDENT GUIDE

MEASURING RELATIVE HUMIDITY AND DEW POINT

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- Small rubber band
- Cotton wick
- Rubber cap
- Ice
- Plastic pipette
- Screw
- Screwdriver
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- Water, room temperature
- 3 plastic-backed, nonmercury thermometers
- 3 colored markers (optional)
- Ruler (optional)

LESSON OBJECTIVES:

You will be able to:

1. Construct a sling psychrometer.
2. Determine direct dew point.
3. Use sling psychrometer to de-termine dew point and relative humidity.
4. Calculate dew point and relative humidity.
5. Read reference tables.

LESSON OVERVIEW:

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ESSENTIAL QUESTION:

How are relative humidity and dew point measured?

TOPICAL ESSENTIAL QUESTION:

What effect does temperature have on relative humidity and dew point?

SAFETY PRECAUTIONS:

- Check that the thermometers are securely attached to the plastic handles before allowing students to swing them. (Teacher may assemble the psychrometers prior to students using.)
- Handle thermometers carefully to avoid dropping.
- Keep control of the psychrometers at all times.
- Always wear eye protection.

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KEY VOCABULARY:

Psychrometry
Dew point
Sling psychrometer
Frost point
Relative humidity

EXPLORE:

In this activity, you will learn to construct and use a sling psychrometer, and utilize different methods to determine relative humidity and dew point levels of air.

PROCEDURE:

Activity 1: Measuring Condensation Point

1. Fill the metal can approximately one-half full with room-temperature water.
2. Place a thermometer in the water and record the initial temperature (°F) in the data table.
3. Slowly add ice to the water and swirl the can gently. As soon as moisture is felt on the outside of the can, note the temperature. This is the dew point temperature. Record in Data Table 1.

NOTE: If large water droplets form on the outside of the can before the final temperature is recorded in step 3, the recorded final temperature will not be accurate. If this occurs, empty and dry the can, and repeat the procedure after the can reaches room temperature.

Data Table 1: Measuring Condensation *If time permits, do at all three locations. If time is a factor, do inside only*

	Inside	Outside in sun	Outside in shade
Initial Temperature (F)			
Condensation Point Temperature (F)			

Activity 2: Construct the Sling Psychrometer

1. To make the wet-bulb thermometer, take a ½" piece of cotton wick and cover the bulb of one thermometer.
2. Attach the wet-bulb thermometer to a dry-air thermometer by placing the two plastic backs together and wrapping a small rubber band close to the bulb ends to hold them together.
3. Put the screw through the aligned holes of the thermometers.
4. Twist the screw carefully into the end of the plastic handle (with the predrilled hole in it) until at least half of the screw is inside the handle.

Activity 3: Sling Psychrometer Measurement

Perform the following steps in three locations (inside a building, outside in the shade and outside in the sun).

1. Using the sling psychrometer you assembled, measure the air temperature using the dry-bulb thermometer. Record this value in degrees Fahrenheit in Data Table 2.
2. Use a pipette and place 2 drops of water on the gauze of the wet-bulb thermometer.

3. Hold the plastic handle in your hand and slowly rotate the thermometers around the screw. The spinning motion will accelerate the evaporation rate of the water.
4. Spin the thermometers on the sling psychrometer for 30 seconds.
5. Immediately check the temperature of the wet-bulb thermometer and record in Data Table 2.
6. Subtract the wet-bulb temperature from the dry-bulb temperature (assuming dry is higher than wet). Record in Data Table 2.
7. Use Reference Table 2 to find the relative humidity by finding the dry bulb temperature in the first column and the difference between dry and wet bulb temperature in the first row. The relative humidity will be the number where the two cross. Record your answer in Data Table 2.

Data Table 2: Sling Psychrometer Measurements

	Inside	Outside in sun	Outside in shade
Dry-bulb Temperature (F)			
Wet-bulb Temperature (F)			
Difference between Dry and Wet Temperatures (F)			
Relative Humidity (%)			

Reference Table 2: Relative Humidity in Percentage (%)

	Differences Between Dry Bulb and Wet Bulb (°F)														
Dry-bulb Temp (°F)	**1°**	**2°**	**3°**	**4°**	**5°**	**6°**	**7°**	**8°**	**9°**	**10°**	**11°**	**12°**	**13°**	**14°**	**15°**
32	90	79	70	60	50	40	31	22	13	4	x	x	x	x	x
34	91	81	72	62	53	44	35	26	18	9	1	x	x	x	x
36	91	82	74	65	56	48	39	31	22	14	6	x	x	x	x
38	92	83	75	67	59	51	43	35	27	19	11	4	x	x	x
40	92	84	76	68	61	53	46	38	31	23	16	9	2	x	x
42	92	85	77	70	62	55	48	41	34	28	21	14	7	x	x
44	93	85	78	71	64	57	50	44	37	31	24	18	12	5	x
46	93	86	79	72	65	59	52	46	40	34	28	22	16	10	4

Reference Table 2: Relative Humidity in Percentage (%)

	Differences Between Dry Bulb and Wet Bulb (°F)														
Dry-bulb Temp (°F)	**1°**	**2°**	**3°**	**4°**	**5°**	**6°**	**7°**	**8°**	**9°**	**10°**	**11°**	**12°**	**13°**	**14°**	**15°**
48	92	83	75	67	59	51	43	35	27	19	11	4	x	x	x
50	93	87	91	74	68	62	56	50	45	39	33	28	22	17	12
52	94	87	91	75	69	63	58	52	47	41	36	31	25	20	15
54	94	88	82	76	70	65	59	54	49	43	38	33	28	23	20
56	94	88	83	77	71	66	61	56	51	45	40	36	31	26	22
58	94	89	83	78	72	67	62	57	52	47	42	38	33	29	24
60	94	89	84	78	73	68	63	58	54	49	44	40	35	34	27
62	95	89	84	79	74	69	64	60	55	51	46	42	38	34	29
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32
68	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38
74	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39
76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44
82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45
84	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45
86	96	92	88	84	81	77	73	70	65	63	60	57	53	50	47

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Reference Table 2: Relative Humidity in Percentage (%)

	Differences Between Dry Bulb and Wet Bulb (°F)														
Dry-bulb Temp (°F)	**1°**	**2°**	**3°**	**4°**	**5°**	**6°**	**7°**	**8°**	**9°**	**10°**	**11°**	**12°**	**13°**	**14°**	**15°**
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49
92	96	90	89	85	82	78	75	72	68	65	62	59	56	53	50
94	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51

Activity 4: Construct the Sling Psychrometer

In Activity 1, you conducted a direct measure of condensation point, also known as dew point. Now you will use the Psychrometric Chart to calculate the dew point.

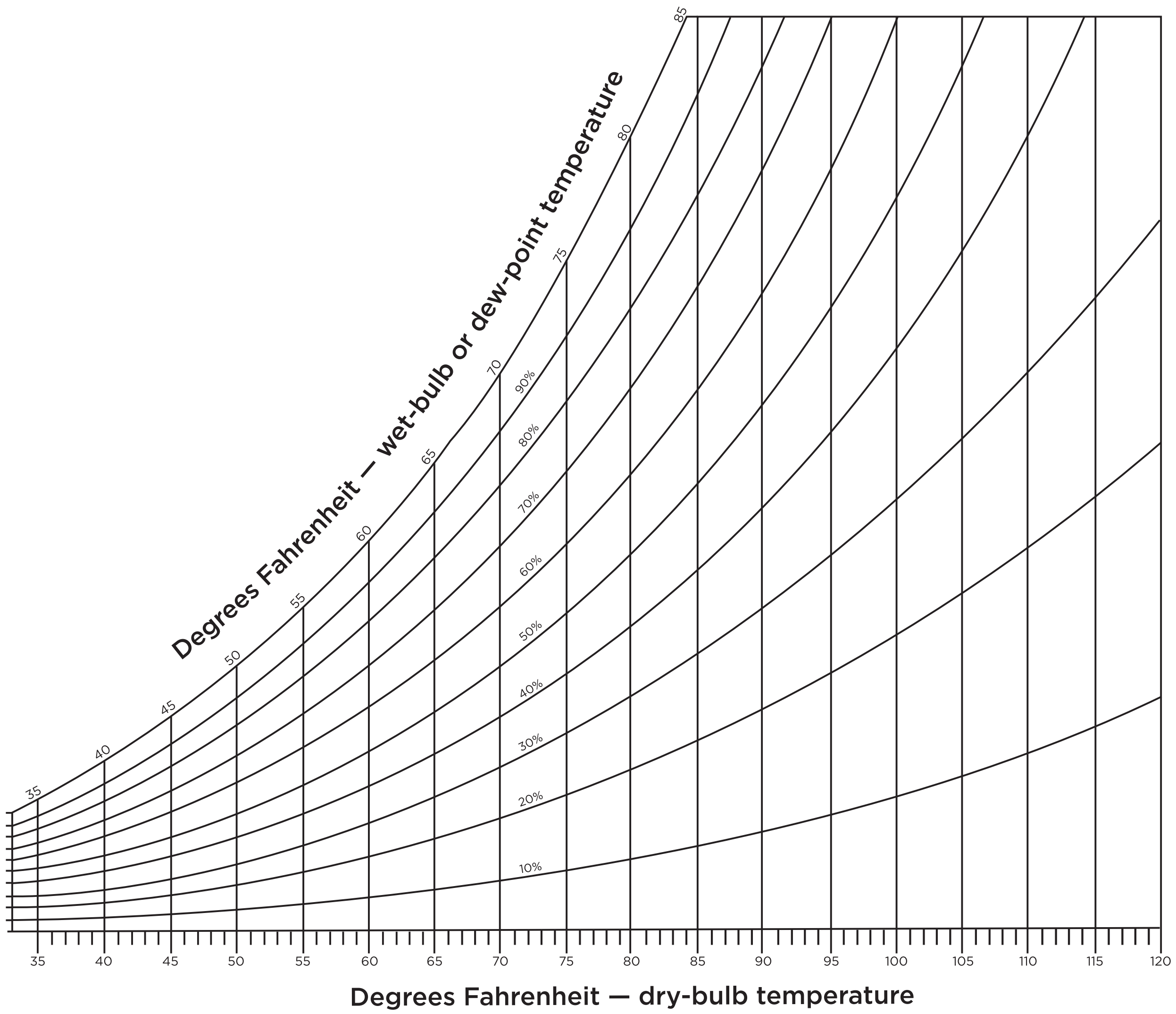
Using the psychrometric chart below, you will use the measurements taken in parts 2 and 3 to find the dew point temperature. It may be helpful to use different colors for the three temperatures (inside, outside in sun, outside in shade).

1. On the psychrometric chart, dry-bulb temperature is located on the x-axis. Find the dry-bulb temperature for inside, and draw a line straight up and down on the chart.
2. On the psychrometric chart, relative humidity is represented by the curved lines starting on the left side. Find the relative humidity for inside, and draw a curved line on the chart.
3. To determine dew point using the chart, find where the dry-bulb temperature line and the relative humidity line cross. From this point, draw a horizontal line straight across to the outermost left curve. This represents the dew-point temperature. Record in Data Table 3.
4. Repeat steps 1-3 for outside sun and outside shade.

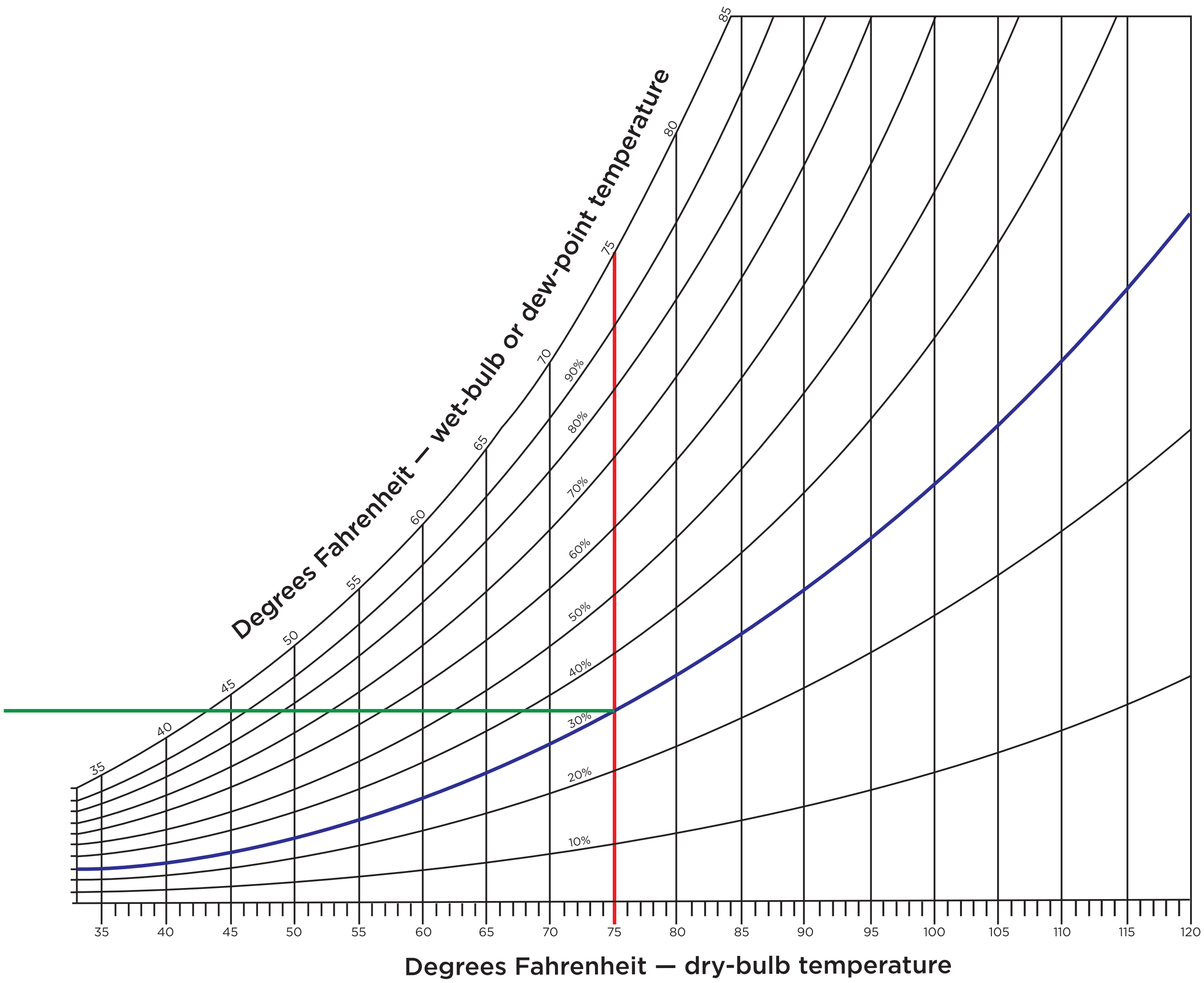
Data Table 3: Dew Point Measurements

	Inside	Outside in sun	Outside in shade
Dew Point Temperature (F)			

Psychrometric Chart



Example of how to complete psychrometric chart:



If dry bulb temperature is 75°F (red line) and relative humidity is 30% (blue line), then the calculated dew point is 43°F (where the green line crosses the outer curved line).

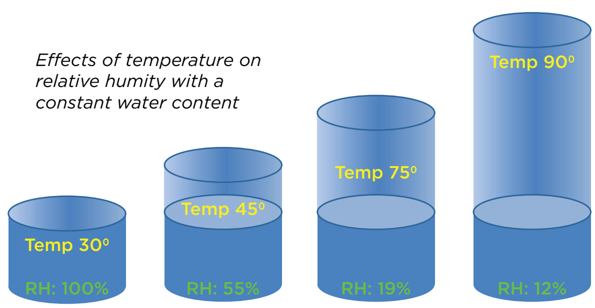
EXPLAIN:

The concepts of relative humidity and dew point are both part of the field of **psychrometry**, or the study of the principles of moisture in the air. The issue of moisture in the air affects all of us on a daily basis in the form of weather. Whether you live in an arid desert region or a lush tropical region, you experience the effects of dry air (atmospheric air comprised of nitrogen and oxygen) and water vapor in the form of humidity, rain, and frost.

Psychrometry is a very important science to agriculture. It is used to create and control micro-environments in livestock facilities, greenhouses and grain bins. Understanding the relationship between water vapor and temperature allows producers to create environments to provide for animal comfort, maximize production, prevent loss and increase profits.

Two underlying concepts are important to the study of psychrometry: temperature and state of matter. As we learned in the water cycle, water exists on Earth in three forms: solid, liquid and gas (vapor). Temperature has an effect on the state water exists in as it influences the speed of the molecules. Water moves from the liquid to the vapor state when it is exposed to high levels of heat (from the sun), causing the molecules to increase their speed and move farther apart from one another and rise into the air filling the spaces between the gas molecules. When temperatures are high, the atmosphere has more energy and will hold more water vapor than when it is cold because the molecules move faster and have more space available. The amount of water vapor the atmosphere will hold is called humidity. On hot days, the air feels sticky and heavy – this is humidity. Geographical regions with more greenery or near large bodies of water have higher humidity than areas like the desert where little water is available for evaporation.

Meteorologists, or weather scientists, measure the humidity in the air in terms of **relative humidity**. This is the percentage of moisture the air is holding compared to the maximum it can hold at a given temperature. It is expressed as a percentage. Relative humidity is important because it influences weather events like cloud formation and precipitation. Clouds form when the air cools enough to cause water vapor molecules to collide and stick together or change phase and condense.



The more humidity in the air, the more clouds will form. For precipitation to occur, the air has to reach 100 percent relative humidity, meaning the air is saturated and cannot hold any more water. The water is released into the atmosphere as rain, snow, sleet or hail.

One way to measure relative humidity is to use a **sling psychrometer**, a device made of two thermometers, One thermometer measures the temperature of the dry air (dry-bulb thermometer) and the other measures the temperature of the air as evaporation occurs (wet-bulb thermometer).

The sling psychrometer can also be used to measure **dew point**. Dew point is the temperature at which air must be cooled for saturation to occur (dew to form). You may be familiar with this concept if you've ever had a cold glass of lemonade on a hot summer day. You probably noticed the glass starts to "sweat." Cold air cannot hold as much moisture as warm air. The cold liquid inside the glass cools the air temperature around it, causing the water vapor in the air to condense on the sides of the glass, returning it to the liquid state. The same concept applies at night when the dew forms on the grass. The air temperature falls after the sun sets, and the cooler air near the ground loses its capacity to hold the water vapor, causing condensation on the grass blades or objects on the ground. These are both examples of the dew point concept – when the temperature around the object is cooled enough to form liquid water. You may also be familiar with the concept during the winter when frost forms on the grass and cars. When the dew point is below freezing (32° F), it is commonly referred to as the **frost point**.

The difference between the air temperature and the dew point indicates whether the relative humidity is high or low. When the air temperature and the dew point are dramatically different, the relative humidity is low. When the air temperature and the dew point are close to the same value, the relative humidity is high. *If the two numbers are equal, then relative humidity is at 100 percent.*

ELABORATE:

1. Compare your calculated values to values reported by a local weather station or the National Weather Service (http://weather.gov). Why might these measurements may be different?
2. Collect data over a period of time and graph their data to show trends over time.
3. The height of cumulus cloud bases can be calculated using the dew point temperature and the surface air temperature.

   Height of cloud base (in feet) = 222 [temperature of air (F) - dew point temperature (F)]

   Use this formula and today's weather data to calculate how high the clouds are.

EVALUATE:

Name: ____

Use knowledge gained from this lesson to complete the questions.

1. Explain, in your own words, why dew point may be different on different days.

____

2. Why might a gardener want to watch the weather when the temperature at night is forecast to be low?

____

____

____

3. What is relative humidity?

____

____

____

4. What effect does temperature have on relative humidity?

5. Why is relative humidity and dew point important to agriculturalists?

6. Which factor influences relative humidity and dew point the most?

7. Using your knowledge of dew point and relative humidity, construct an explanation for why frost forms on a car overnight when temperatures are low and why condensation forms on the outside of a glass of ice water. Be sure to provide evidence from your investigation and/or personal experience in your explanation.