DETERMINING THE DEW POINT

The dew forms when the saturated air cannot hold any more water vapor. The dew forms on the grass...on the leaves...the flowers...the dragonflies.

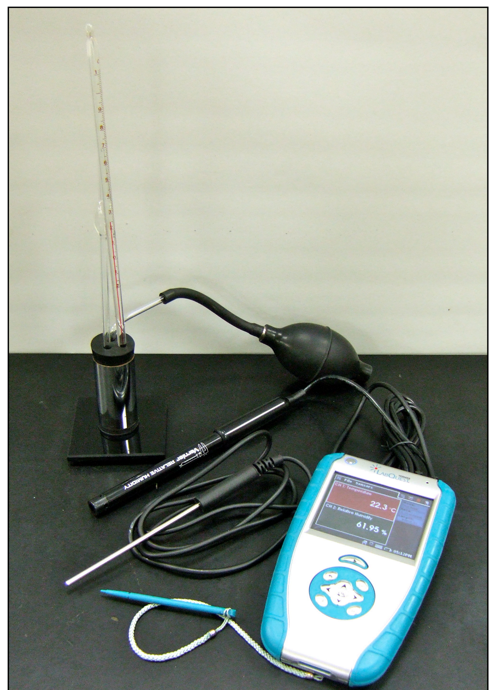
INTRODUCTION

What does a lab about weather have to do with a chapter on heat and fluids? Well, everything. The weather we experience every day is the exchange of energy through fluid media on a global scale. Seriously. Rather than try to figure out global weather patterns, though, let's focus ourselves on something a little closer to home. Where does that dew come from? It didn't rain last night, and yet the grass is wet. No, it wasn't the automatic sprinkler system, either. The drops of dew on the leaves of grass formed right where they are, from water vapor in the air.

If we are going to talk about water vapor in the air, then we are talking about humidity. And anyone who has spent a summer here in central Arkansas understands the idea of humidity. When we watch the weather on television, we are always told that the *relative humidity* is X%. On a summer day, 75% RH is typical here in Conway (and higher %s are also to be expected). Relative to *what*, though? Relative humidity is a comparison between how much water vapor is in the air and the maximum amount of water vapor the air can hold. So a 75% RH means that the air is 75% saturated with water vapor.

The maximum amount of water vapor that the air can hold depends on the temperature. It probably won't surprise you to know that warm air can hold more water vapor than cold air. For example, at 30°C (86°F), the air can hold a maximum of 30 g of water vapor per cubic meter, but at 23°C (73°F) it can hold only 20 g/m^3. So, let's say it actually is 30°C outside. The air is moist, but not saturated–say it contains only 20g/m^3. The the RH can be calculated with a simple ratio:

$$RH = \frac{H_2O\ content}{saturation\ H_2O} = \frac{20\,\frac{\text{g}}{\text{m}^3}}{30\,\frac{\text{g}}{\text{m}^3}} = 67\%$$



Read the dew point temperature the old-fashioned way: with a thermometer.

Now let's circle back around to the dew point. Imagine that the temperature drops quickly (perhaps the sun sets). If it only goes down by a degree or two, then the air can still hold the water vapor. But if the temperature drops to 23°C, the air will be saturated. Any further decrease in temperature, and the air can't hold the water vapor. Where does it go? It's right there on the grass. The water vapor condenses out of the air. In our example, 23° is the dew point, which is quite literally the point at which dew begins to form. Measuring these values can be done easily, but we need to be very careful about drawing general conclusions. For example, you cannot say that 23° is *always* the dew point when it is 30° outside. If the air is more or less saturated, the actual dew point will be higher or lower.

OBJECTIVES

- Define the idea of relative humidity
- Experimentally determine the dew point
- Calculate the dew point from the relative humidity
- Compare the the measured and calculated dew point values
- Relate the relative humidity to the heat index

EQUIPMENT

- Vernier LabQuest
- Temperature probe
- Relative humidity probe
- Dew point apparatus
- Isopropyl alcohol
- Thermometer

EXPERIMENTAL PROCEDURE

- Use the LabQuest to measure and record the room temperature and the relative humidity.
- The dew point apparatus is shown in the photograph. Fill the metal cup approximately ½–⅔ full with isopropyl alcohol and stopper securely.

- The rubber stopper should have a right–angle tube through one hole. To this tube, attach the aspirator bulb if it is not already in place.
- A thermometer should be inserted through a second hole. When the metal cup is filled with alcohol and stoppered, both the thermometer bulb and the aspirator tube should be below the surface of the liquid.
- The third hole should have the outlet tube, which is a narrow glass tube with a bulge at about its midpoint. The base of the outlet tube should not protrude into the liquid.
- Squeeze the aspirator bulb to bubble air through the alcohol. As you are bubbling, watch the metal cup and the thermometer. When condensation begins to appear on the cup, record the temperature.
- Stop bubbling and allow the film of condensation to disappear. When the metal cup is free of condensation, resume bubbling. Once again, record the temperature as soon as the condensation begins to appear.
- Repeat the process until you have recorded the temperature five times.

Data & Analysis

If you have not already, organize your data into a neat table in your lab notebook.

Room Temperature (°C)	Relative Humidity (%)	Dew Point (°C)					Average Dew Point (°C)
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	

1. Compute the average value for your dew point measurements and record it.
2. Use the table to find and record the saturation level of water vapor for the room temperature and the actual water vapor content for the dew point temperature.
3. Calculate the relative humidity as the ratio of actual to saturation water vapor as shown in the example above.
4. Use the relative humidity to calculate the dew point. Calculate the actual H_2O content of the air, then use the table to correlate it with a temperature:
$$H_2O\ content = (RH) \times (saturation\ H_2O)$$
Use your judgement when comparing the calculated H_2O content to the table; you might have to estimate the dew point temperature (for example, if your calculated value for the H_2O content is 17.9 g/m^3, this value is closer to 18.1 and 21°C than it is to 17.1 and 20°C).

Water Vapor as a Function of Temperature

T (°C)	H_2O (g/m^3)	T (°C)	H_2O (g/m^3)	T (°C)	H_2O (g/m^3)
10	9.330	20	17.118	30	30.020
11	9.395	21	18.143	31	32.040
12	10.574	22	19.222	32	33.449
13	11.249	23	20.355	33	35.274
14	11.961	24	21.546	34	37.167
15	12.712	25	22.796	35	39.137
16	13.505	26	24.109	36	41.279
17	14.339	27	27.487	37	43.475
18	15.218	28	26.933	38	45.751
19	16.144	29	28.450	39	48.138

5. Compare the measured dew point temperature with the dew point you calculated. Calculate the **percent error**:
$$\%\ error = \left(\frac{calculated - measured}{calculated}\right) \times 100$$
6. Look at the water vapor table, and comment about the trend. It's obvious that the air holds more water vapor at higher temperature, but is this a linear relationship? What would a graph of this data look like?
7. Convert the room temperature from °C to °F, using:
$$°F = \frac{9}{5}(°C) + 32$$
8. Use the table to determine the heat index. Comment on where (and what time of year) your data was collected to explain why the heat index is the same or different as the measured temperature.

Heat Index
how hot the combination of temperature and humidity feels

Relative humidity (percent) across; Air Temperature (°F) down

Air Temperature (°F)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
140	125																				
135	120	128																			
130	117	122	131																		
125	111	116	123	131	141																
120	107	111	116	123	130	139	148														
115	103	107	111	115	120	127	135	143	151												
110	99	102	105	108	112	117	123	130	137	143	150										
105	95	97	100	102	105	109	113	118	123	129	135	142	149								
100	91	93	95	97	99	101	104	107	110	115	120	126	132	138	144						
95	87	88	90	91	93	94	96	98	101	104	107	110	114	119	124	130	136				
90	83	84	85	86	87	88	90	91	93	95	96	98	100	102	106	109	113	117	122		
85	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	95	97	99	102	105	108
80	73	74	75	76	77	77	78	79	79	80	81	81	82	83	85	86	86	87	88	89	91
75	69	69	70	71	72	72	73	73	74	74	75	75	76	76	77	77	78	78	79	79	80

Extreme Danger (130°F or higher). Heatstroke or sunstroke likely.
Danger (105 - 129°F). Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution (90 - 105°F). Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution (80 - 90°F). Fatigue possible with prolonged exposure and/or physical activity.

9. On a summer day in Arkansas, 95°F is pretty typical. So is an RH = 45%. Meanwhile, in Phoenix the temperature is probably closer to 105°F, but the RH = 10%. Compare the heat indices (and think about the cliché "It's a dry heat!").