

**MEASURING CLIMATE CHANGE**  
Advanced topics in Earth Science  
**EASC 560-R0X**  
**(Spring or Fall 2007)**

**Course Description**

This course is designed for middle and high school teachers of earth science and general science and will provide instruction in advanced content for teachers acquiring professional stage licensure. Topics will include data collecting, analysis and interpretation of climate data. Teachers will gain experience through computer and Internet modules, field observations and experiments with physical models in the classroom. Emphasis will be placed on current issues and innovative use of available resources. A course web page will provide access to content material and updates.

**Course Requirements**

1. Complete all class and online requirements identified in the syllabus. This course involves 15 hours of instruction (1 graduate credit hour) as outlined below.
2. Complete a set of three experiments that include the following components: collecting data, graphing techniques, interpretation of patterns, working with fractions and geometry, and scientific writing skills.
3. Develop one activity that utilizes Internet resources to motivate *critical thinking, inquiry, use of mathematics, and understanding the scientific method*. You may use concepts stated in *Strand 1: Earth and Space Science* and *Strand 2: Physical Sciences*, of the *Science and Technology/Engineering Curriculum Framework* for Massachusetts. Furthermore, the activity should be appropriate for the grade level you are teaching.
4. Create a detailed 3-5 page lesson plan of your activity that provides sufficient background information for understanding the content of your online activity. The paper must be submitted to the instructor in digital format (MS Word document is preferred).
5. Make classroom presentation of an activities that effectively incorporates the components in (2.) above.
6. Complete at pre- and post- test during the first and last class meetings (use to measure knowledge gain).
7. The class will include hands-on activities designed to teach the content in question. The activities will be either directly applicable or adaptable to the participants' own classrooms. A typical class will involve review of a previous written assignment, instruction in the materials and methods to be employed, completing hands-on laboratory activities, a short written summary, and discussion sessions. Lectures will present content using a black/white-board, multimedia technology, and interactive demonstrations.
8. Students should purchase a 3-ring binder and digital storage device, such as a USB flash drive. Students will receive additional materials necessary to complete experiments and assignments.

## **Course Content and Expected Outcomes**

1. Gain the knowledge necessary to explain and discuss advanced conceptual questions including, among others, “global warming,” climate change, climate variability, scales of climate, paleoclimate, meteorological instrumentation, remote sensing, and climate projections based on statistics.
2. Acquire skills and ability to effectively use hands-on activities for teaching additional concepts of climatology.
3. Understand the underlying key concepts of weather and climate including: temperature, types of heat transfer, pressure, wind, moisture, and precipitation.
4. Understand the relationships between the key concepts in (3.).
5. Classes will consist of interactive lessons using simple physical models, climate resources on the Internet, field observations, and group presentations to teach the content in (3.) above.
6. Construct and complete experiments to reinforce concepts including the three major types of heat transfer, specific heat, differential heating, and cloud formation.
7. Install an automatic weather station, and download, store and analyze the variables.
8. Interpret results of experiments and relate to key concepts using tables and graphical analysis.

## **Course Prerequisites**

Eligible to sign up for a graduate level courses at Bridgewater State College. This course is transferable to the Masters program for middle school science at Bridgewater State College.

## **Textbooks and Reference Materials:**

Sorbjan, Z., 1997: Hands-On Meteorology: Stories, Theories, and Simple Experiments. American Meteorological Society. 306 pp.

The Glossary of Weather and Climate, 1996: American Meteorological Society. 272 pp.

LeMone, M. A., 1993: The Stories Clouds Tell. American Meteorological Society, 32 pp.

O’Hare, Sweeney, and Wilby, 2005: Weather, Climate and Climate Change: Human Perspectives, 444 pp. Prentice Hall. ISBN-13: 9780130283191.

**Schedule** (Class will meet five sessions of three hours each for a total of 15 hours)

### ***First session***

Introduction to weather and climate  
Overview of Key Concepts: temperature, heat transfer, pressure, wind, moisture, and precipitation  
Pretest  
Setting up field measurements of climate  
Written assignment: pre-lab for experiments

### ***Second session***

Discussion of pre-lab  
Lab experiments of key concepts  
1) differential heating, 2) pressure and wind, and 3) moisture and precipitation  
Reading assignment: Climate Change: IPCC Report

### ***Third session***

Discussion of reading assignment and summary of IPCC  
Relating IPCC report to Key Concepts  
Computer lab exercise: Internet resources for climate data and methods of interpretation  
Assignment: gathering evidence for group presentation

### ***Fourth session***

Collecting field measurements  
Computer lab exercise: analyzing measurements and methods of interpretation  
Assignment: preparing group presentations

### ***Fifth session***

Group presentations and posttest

## **PROGRESS REPORT (completed Spring and Summer of 2006)**

My objective was to produce a highly interactive climate change course for K-12 teachers, targeting physical science teachers at the middle and high school levels. This course heavily incorporates field observations, lab experiments, graphical, and presentation methods of learning and communicating results. I have experience teaching climatology and meteorology over my past 6 years at BSC, so I drew most of my ideas from GEOG 221: Meteorology, GEOG 321: Meteorology II, and GEOG 222: Climatology. I also have about 4 years of experience teaching EASC 560: Topics in Earth Science for middle and high school in service teachers, so I understand the content and hands-on lab needs of K-12. I have not taught a EASC 560 (graduate) course on climate change, which I consider an increasingly significant issue that K-12 students must face in the near future. In developing this 1 credit-hour course (five 3-hour meeting times per semester), I tailored activities to meet several key concepts under the Science Frameworks for Massachusetts.

During the past summer (2006), I gathered my favorite labs from the GEOG 221/321/222 courses and integrated key concepts into the activities. In addition, I created a field activity for measuring climate change and variability on a local scale, such as the region around a school. Although I incorporate high technology in observing weather variables for climate assessment, I include alternative low technology methods for resource strained school districts. I am in the process of developing an Internet activity that promotes use and proper interpretation of existing weather and climate data available from the National Climatic Data Center and other reliable web sites. Finally, I will have the class read parts of the most comprehensive and widely accepted report on climate change, the Intergovernmental Panel on Climate Change (IPCC). The newest version will become available to the public in 2007. I will divide the class into four groups, each responsible for preparing a presentation summarizing the primary IPCC components. I intend to teach this class during the Spring 2007 or Fall 2007 semester.

### Attachments:

- 1) Sample of lab experiment for teaching key science concept (Transformations of Energy)
- 2) Sample of field activity for measuring climate variables (Local Climate Change Assessment)
- 3) Group Presentation guidelines (Global Climate Change Assessment)

# (1) *Transformations of Energy* (60 points total)

## Part I. Radiation, Albedo and Specific Heat:

**Purpose:** Observe and record the rate of temperature increase for objects with different color, specific heat, and roughness subjected to the same amount of solar radiation.

**Problem:** The effect of material properties on rate of temperature increase.

**Hypotheses (6 pts):** It is your job to come up with three hypotheses to test the effects of color, surface roughness, and specific heat on temperature.

**a. Color:**

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**b. Roughness:**

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**c. Specific Heat:**

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**Objectives:**

- A. Each group of two (2) will build a solar energy collector out of a Styrofoam cooler
- B. Describe the effects of 6 different types of materials (color, specific heat, and roughness)
- C. Plot the air and surface temperature vs. time for each of the 6 solar energy collectors
- D. Collect and compare the results of each of the 6 group experiments

**Materials (per group):**

- 1) 1 Styrofoam cooler
- 2) 2 Clear plastic cups
- 3) 2 Liquid in glass Thermometers
- 4) 1 100-Watt desk-mounted lamp (will serve as “sun” unless skies are clear and wind is calm)
- 5) 1 metric length scale (ruler)

**Procedure:**

- a. Prepare your samples in experiment #1 for testing (method discussed by instructor during lab period)
- b. Place the Styrofoam cooler so that the open end is about 10 cm from the edge of the lamp
- c. Place your samples into the Styrofoam cooler so that you can read the thermometer
- d. When all 6 groups are ready to start, begin recording temperature every 30 seconds for 15 minutes.
- e. Repeat this procedure for experiments #2 and #3

## Experiment #1: Surface Color and Albedo

1. (2 pts) Temperature (nearest half deg. **Celsius**) of dark and light colored samples for 15 minutes.

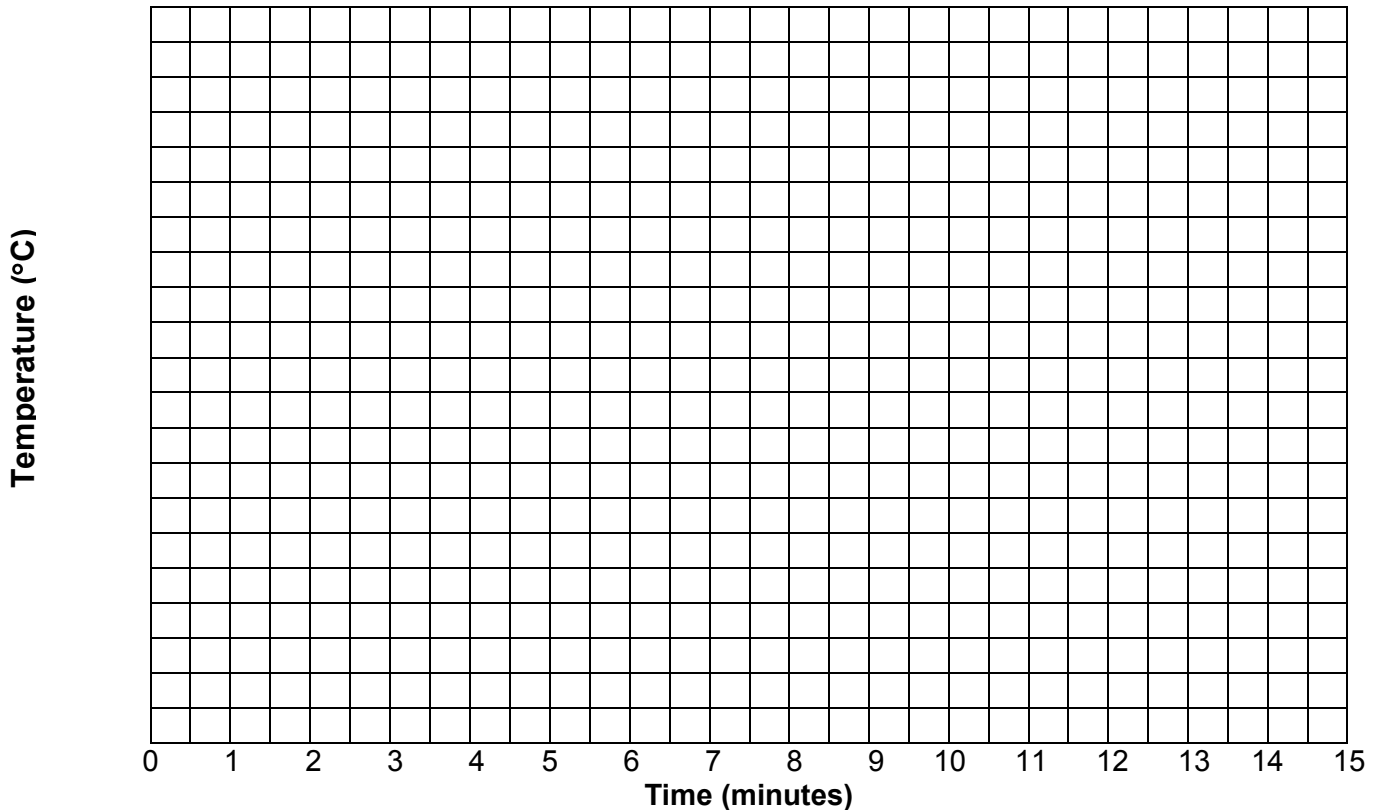
**Table 1: Temperature of sample #1: White paper** covering bulb of thermometer

<i>minutes</i>	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
Temp.																
<i>minutes</i>	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	X
continued																X

**Table 2: Temperature of sample #2: Black paper** covering bulb of thermometer

<i>minutes</i>	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
Temp.																
<i>minutes</i>	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	X
continued																X

2. (4 pts) Plot the temperature vs. time for the two samples on the grid below. Label the temperature axis from minimum to maximum temperature observed above. You may use a spreadsheet to create a graph and attach it to your lab. Label each line by color or use a legend (key).



## Experiment #2: Surface Roughness and Albedo

3. (2 pts) Temperature (nearest half degree **Celsius**) of rough and smooth samples for 15 minutes.

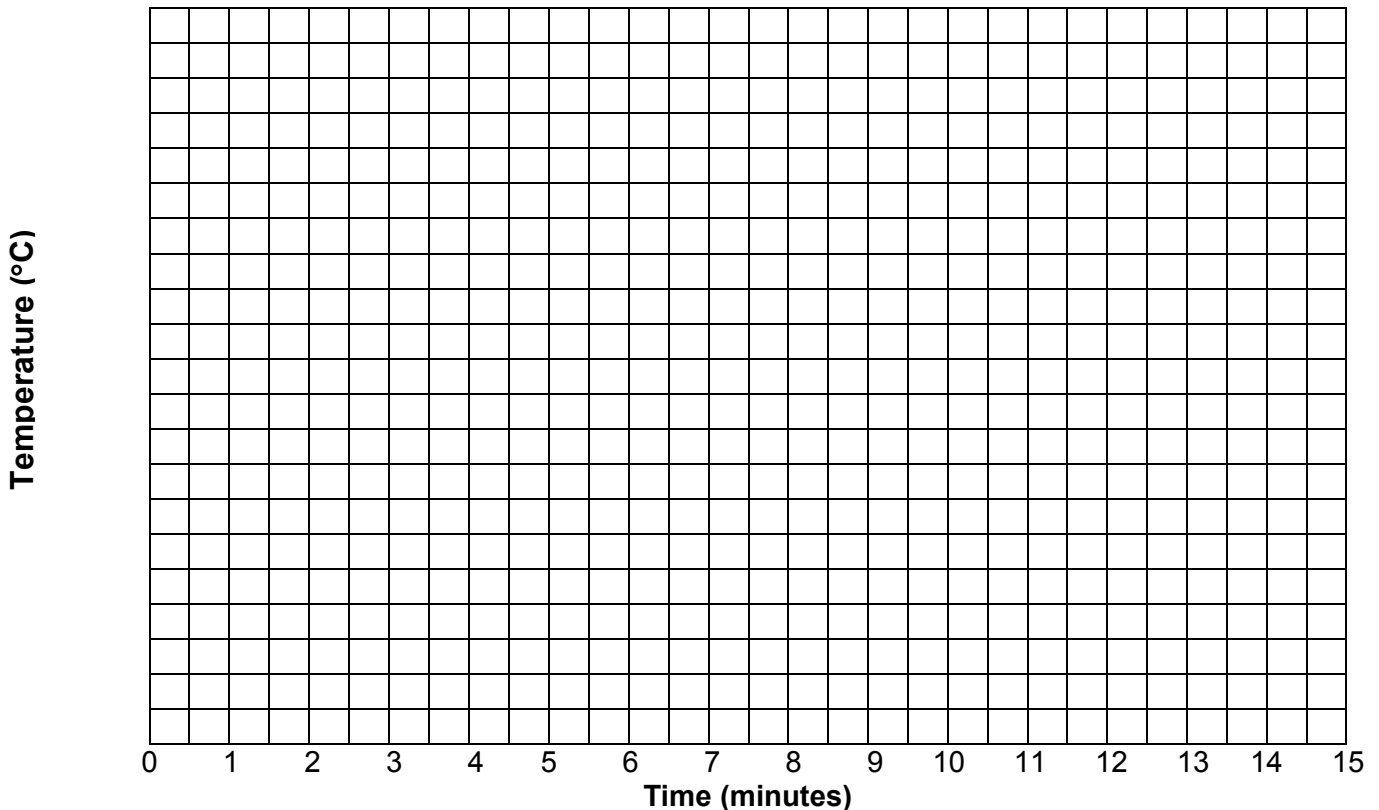
**Table 3: Temperature of sample #3: Smooth surface** covering bulb of thermometer

<i>minutes</i>	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
Temp.																
<i>minutes</i>	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	X
continued																X

**Table 4: Temperature of sample #4: Rough surface** covering bulb of thermometer

<i>minutes</i>	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
Temp.																
<i>minutes</i>	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	X
continued																X

4. (4 pts) Plot the temperature vs. time for the two samples on the grid below. Label the temperature axis from minimum to maximum temperature observed above. You may use a spreadsheet to create a graph and attach it to your lab. Label each line as smooth or rough or use a legend (key).



### Experiment #3: Specific Heat

5. (2 pts) Temperature (nearest half degree **Celsius**) of different specific heat samples for 15 minutes.

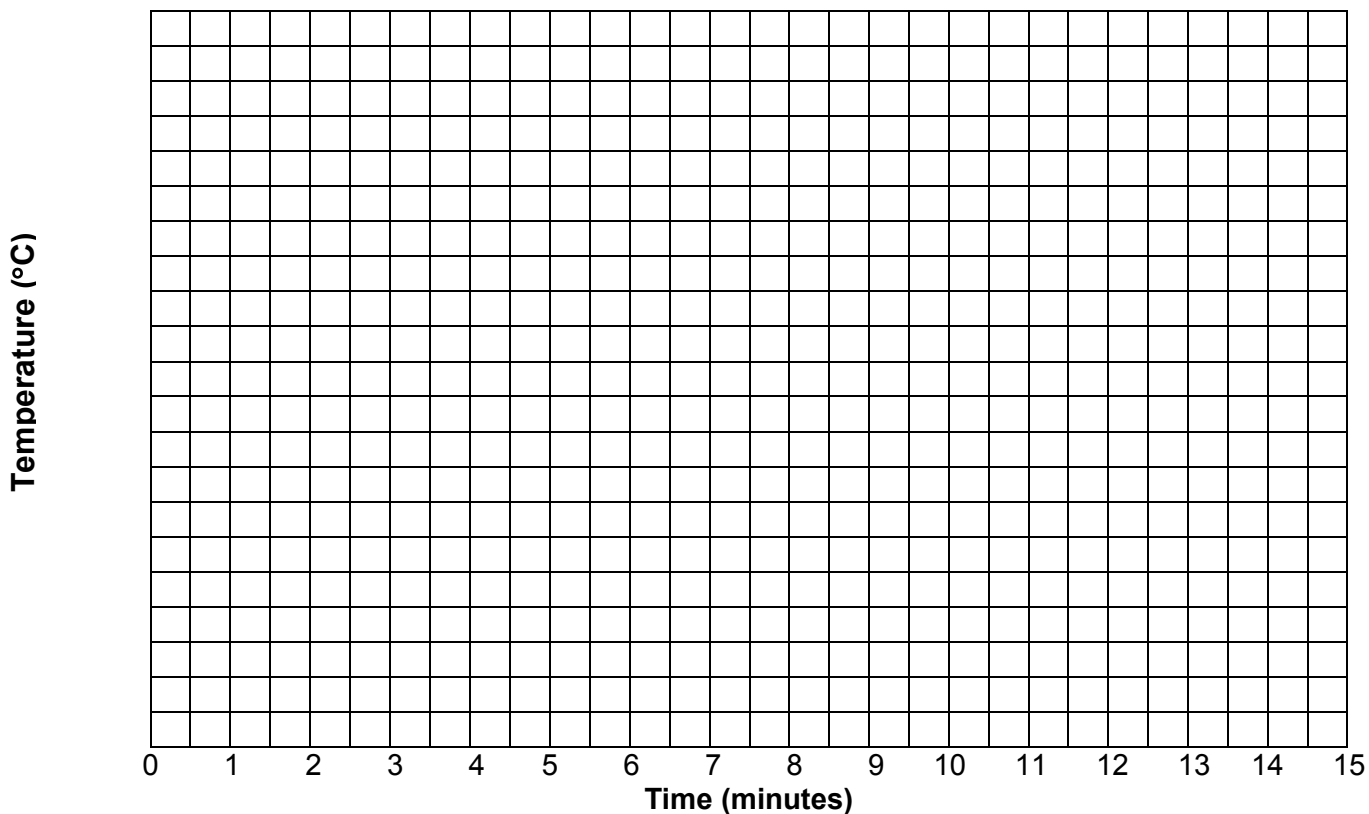
**Table 5: Temperature of sample #5: Water (1/4 full)**

<i>minutes</i>	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
Temp.																
<i>minutes</i>	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	X
continued																X

**Table 6: Temperature of sample #6: Dry Sand (calculate amount to = mass of water)**

<i>minutes</i>	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
Temp.																
<i>minutes</i>	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	X
continued																X

6. (4 pts) Plot the temperature vs. time for the two samples on the grid below. Label the temperature axis from minimum to maximum temperature observed above. You may use a spreadsheet to create a graph and attach it to your lab. Label each line as sand or water or use a legend (key).



7. (2 pts) Of all six samples, which one produced the greatest temperature change during the experiments? Which one produced the smallest temperature change.

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8. (4 pts) Of all six samples, which one warmed up the fastest? From the graph, estimate the rate ( $\Delta\text{Temp} \div \Delta\text{Time}$ ) of temperature change for this sample; show your work below. Use only the portion of the graph that is changing from one minute to the next (the sloped portion). Is the temperature rising at a constant rate (is the line straight)?

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9. (3 pts) Of all six samples, which one warmed up the slowest? Estimate the rate ( $\Delta\text{Temp} \div \Delta\text{Time}$ ) of temperature change for this sample; show your work below. Is the temperature rising at a constant rate (is the line straight)?

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## Part II. Conduction and Convection

**Purpose:** Observe the changes that occur during a demonstration of an open and an “isolated” system.

**Questions:**

1. How can you boil water with a paper cup and a candle?
2. How can you turn a propeller with a candle?

**Hypothesis:** You will develop hypotheses to test possible answers to the questions above

**Objectives:**

- A. Demonstrate how convection and conduction transfer heat from a candle to a cup of water
- B. Construct a simple propeller and show how heat from a candle causes it to turn
- C. Answer the questions provided at the end of this part of the lab

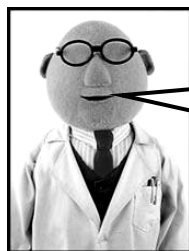
**Materials:**

- 1) 1 candle
- 2) 1 small paper cup
- 3) 1 ring stand with clamp to hold the cup or propeller
- 4) 1 ordinary pencil with eraser
- 5) 1 push-pin
- 6) 1 piece of foil (enough to cut to a diameter of 8 to 10 cm)
- 7) 1 pair of scissors

**Procedure experiment 1:**

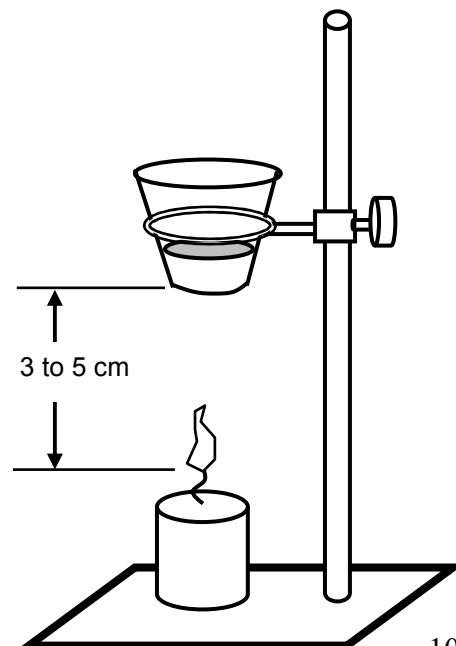
**Boil water in a cup** (see diagram for setup):

- a. Set the candle on the base of the ring stand
- b. Set up the ring stand (or clamp) to hold the paper cup 3 to 5 cm above a candle wick
- c. Fill the cup  $\frac{1}{4}$  full with cool water
- d. Place the cup in the ring stand and light the candle (with match, lighter or fire starter)
- e. Observe the bottom of the cup may turn black, but will not burn as the water temperature rises
- f. End the experiment when the water begins to boil (bubbles rise from the bottom of the cup)



Recording observations and finding patterns can lead to discovery! Please state your hypothesis below

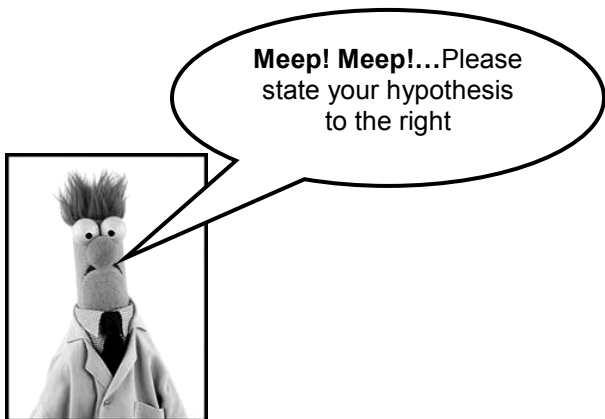
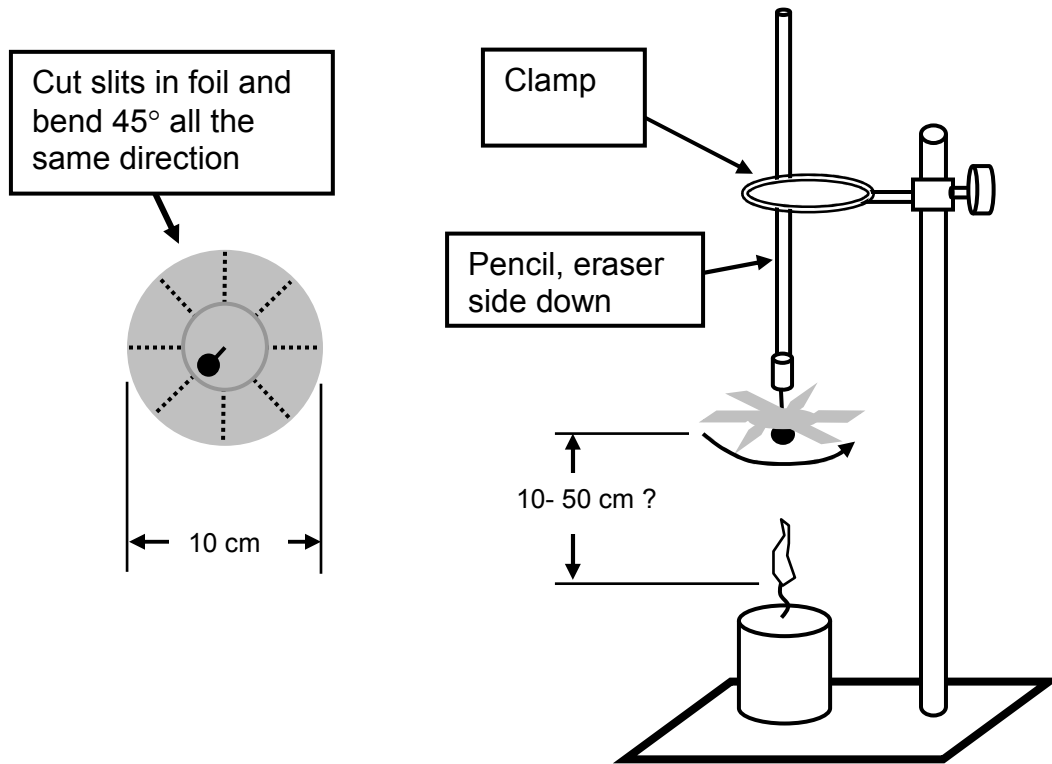
Hypothesis (2 pts):



**Procedure experiment 1:**

**Turning a propeller with a candle** (see diagram for setup):

- Set the candle on the base of the ring stand and set the ring as high up as possible
- Trace a circle (with a cup or glass) onto the aluminum foil and cut it out with scissors
- Cut 8 3-cm deep slits around the edges of the foil (see diagram below)
- Bend the edges (about 45 degrees) of the foil to produce an effective (turning) propeller
- Push the pin as close to the center of the propeller as possible
- Pin the propeller to the end of the eraser on the pencil (blow lightly on the propeller to test it)
- Light the candle and affix the pencil to the ring stand with the propeller horizontal between 10 and 50 cm above the candle's wick; try 10, 20, 30, 40 and 50 cm to see the effect.
- Watch the propeller turn and think (critically) about why this is happening



Hypothesis (2 pts):

**Questions (part II):**

**1. (5 pts)** Discuss the types of energy transfer that cause the water's temperature to rise in the cup. The candle is hot the water is cool; which direction is energy flowing? Think about the type of material (air, paper, water) that transfers the energy. Why do you think the cup does not burn? What would happen to the water in the cup if you let the experiment run for a long time?

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**2. (5 pts)** Discuss the types of energy transfer that cause the propeller to turn. Think about the type of material that transfers the energy. If work is a force times distance, how is work done in this experiment? What happens to the density of air as the temperature rises around the flame? What happens to the volume of the air above the candle as it rises? What do you think would happen if you had two candles under the propeller?

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**2. (4 pts)** How do the experiments in Part III relate to the transfer of heat from the Earth's surface to the atmosphere?

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## (2) Local Climate Change Assessment [Field Measurements and Analysis]

### Differential Heating of BSC (Observations and Excel Graphing)

Write-up due at end of lab period

#### Purpose:

Gather evidence and analyze how differential heating from one landscape to another causes variability of surface and air temperature. Discuss the effects of albedo and other surface properties of different landscape types.

*Lab#3 requires both independent and group work.* You will each be assigned to a particular field site on campus. You will each have several weather instruments to record the air temperature, relative humidity, wind speed, and surface temperature of your site at about the same time of day. After the field observations, you will work as a team to use Excel to combine your observations in a table and then proceed to calculate the average and variability (standard deviation) of all measured weather variables (the instructor will demonstrate).

#### Objectives:

Measure and analyze the variability of surface and weather conditions at different locations on BSC campus (use map, attached, to determine your site). Analyze, compare and explain your results as a team. Write up your lab independently (see below).

#### Procedure:

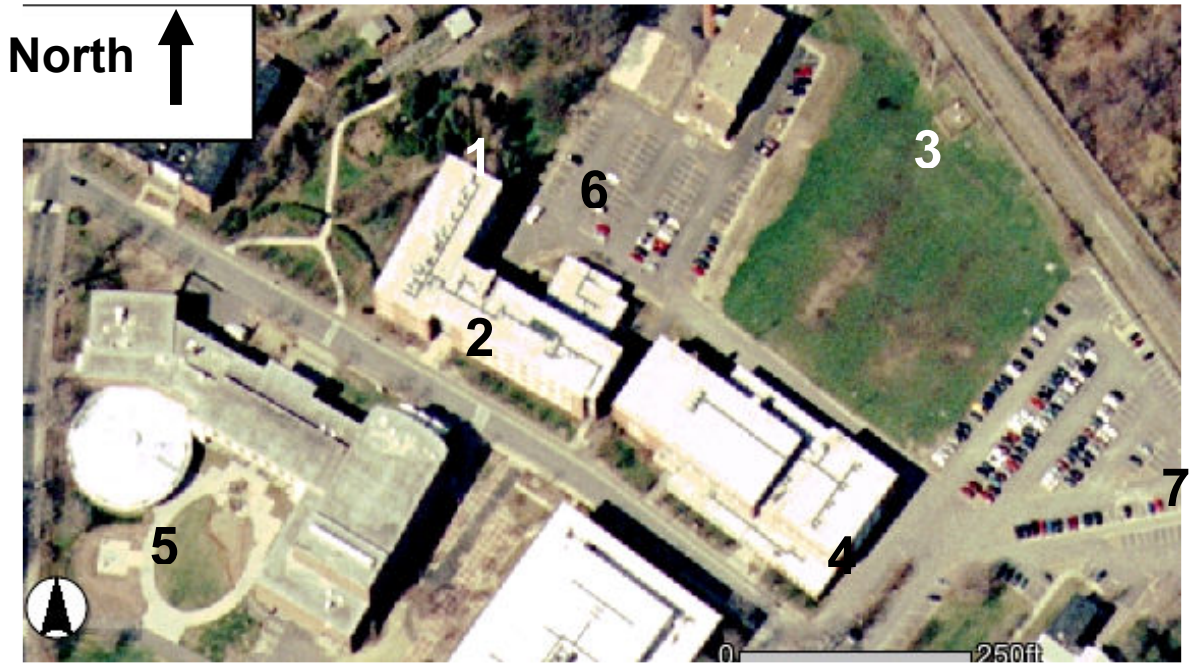
- A. Create a table or recording your field observations of the following variables:
  - 1) Air temperature at standard height of 2 m above ground
  - 2) Humidity at 2 m
  - 3) Wind speed at 2 m
  - 4) Surface temperature using IR thermometer (do not allow direct sunlight to enter the hole)
  - 5) Surface temperature using flip-stick thermometer (place on surface or about 1 cm below)
- B. Record observations at your field site using handheld digital instruments (descriptions attached):  
(take average at one-minute intervals for 10 minutes)
  - 1) Propeller Anemometer
  - 2) Combination Temperature and Humidity probe
  - 3) Non-contact Infrared thermometer
  - 4) Flip-stick thermometer
- C. Describe the surface type and surroundings at your location
- D. Calculate the mean (average) and variability (standard deviation) of all five variables using Excel
  - 1) Gather all observations and record into a common spreadsheet that you can all have access to
  - 2) Use functions for Average and Standard Deviation for each variable
  - 3) Graph air temperature versus relative humidity to determine if the two are related
  - 4) Graph air temperature versus the two surface temperatures (IR and probe) to find relationship
  - 5) Graph the air temperature and probe surface temperature versus the site location to determine which direction (up or down) that sensible heat is flowing
- E. Discuss causes for differences in each variable between the five sites and explain why? Use your knowledge of energy balance and meteorology to discuss the graphs from D. above.

**Grading:** A written summary is required for all labs and it should include the following for grading:

- 1) Title and purpose (explain the reason for doing and goals of the lab) **[5 points]**
- 2) Methods (discuss the techniques, including materials, software, facilities, etc...for doing the lab) **[10 points]**

- 3) Analysis of results (use tables, graphs, and equations to show your results) **[20 points]**  
 4) Conclusions and future work (discuss briefly what you found from this lab and how it relates to meteorology + what you would like to add to or change about the lab in the future) **[10 points]**

***Aerial Photograph (ref. MassGIS) and measurement sites***



**Table of Site numbers and locations (you may add you own)**

1. Japanese garden (beneath the trees)
2. On the roof of the science building (see instructor for key and access)
3. In front of the automatic weather station on the northeast end of the practice field
4. At the base of the southeast-facing wall of the Kelly Gymnasium
5. In the middle of the open space behind the Campus Center
6. Science parking lot
7. Tunnel to west campus
8. other site of your choice

## Digital Anemometer:

Display LCD 4 digits

Function - Range - Resolution

Wind Speed:

0.4-30.0m/s 0.1m/s +(2%+1d)

1.4-1.8km/h, 0.1km/h  $\leq$ 25m/s

80-5910 f/min of/min

0.8-58.3 knots

It measures wind speed at :

m/s ( meters per seconds)

km/h( kilometers per hour)

ft/m ( feet per minute)

knots( nautical miles per hour)

-Temperature: 0 °C a 60 °C

-Precision:  $\pm$  (2% +1dígito)

-With (DATA-HOLD)

-Sensor independent

-Diameter of sensor: 72 mm

-Power : 9 V/ 6F22



This instrument is hand-held and measures wind speed and air temperature.

**Infrared non-contact thermometer:** Allows measurement of surface temperature without contact.



Circle or Dot Laser Sighting

Range: -20 to 420°C (0 to 788°F)

Resolution: 1°C/1°F

Repeatability:  $\pm$ 1°C

Emissivity: 0.95 Fixed

Spectral Response: 6-14 mm

Optical Field of View , D:S = 8:1

Response Time: 500 ms

Accuracy: -20 °C to 100°C: 2°C; 101°C to 420°C:  $\pm$ 3%

Storage Ambient: -20 to 50°C Less than 90% of Humidity

Operating Ambient: 0 to 50°C Less Than 80% of Humidity

Ambient Temperature  $\pm$ 5°C Calibrated by Black Body

Emissivity at 0.95

## Digital Hygrometer, Humidity and Temperature meter:



### Specifications

Display: 3 1/2 digit LCD

Low Battery Indication: A symbol is displayed when the battery voltage drops below the operating level

Battery Life: 200 hours, typical use

Operating Ambient: 0 to 50°C (32 to 122°F), at <75% R.H.

Storage Ambient: -20 to 60°C (-4 to 140°F), 0 to 80% R.H. with battery removed from meter

Accuracy: Stated accuracy at 23°C ±5°C (73°F ±9°F), <75% R.H.

Dimensions: 167 H x 48 W x 24 mm D (6.57 x 1.89 x 0.95")

Weight: 87 g (3 oz) incl. batteries

### Temperature

Sensor: Thermistor

Range: -20 to 60°C (-4 to 140°F)

Resolution: 0.1°C (0.1°F)

Accuracy:

±0.5°C 0 to 45°C;

±1°C -20 to 0°C, 45 to 60°C;

±1°F 32 to 113°F

±2°F -4 to 32°F, 113 to 140°F

### Relative Humidity:

Sensor: Capacitive humidity sensor

Range: 0% to 100% R.H.

Resolution: 0.1% R.H.

Accuracy:

±2.5% @ 25°C (77°F),

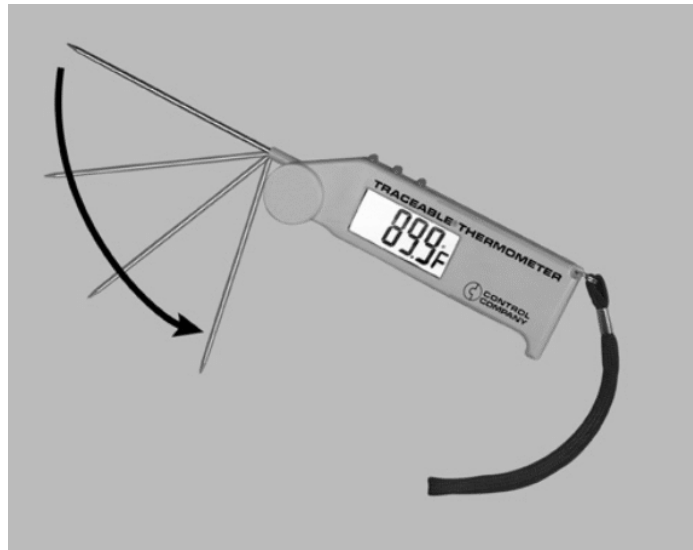
10% to 90% R.H.,

±5% @ 25°C (77°F),

0% to 10% R.H., 90% to 100% R.H.

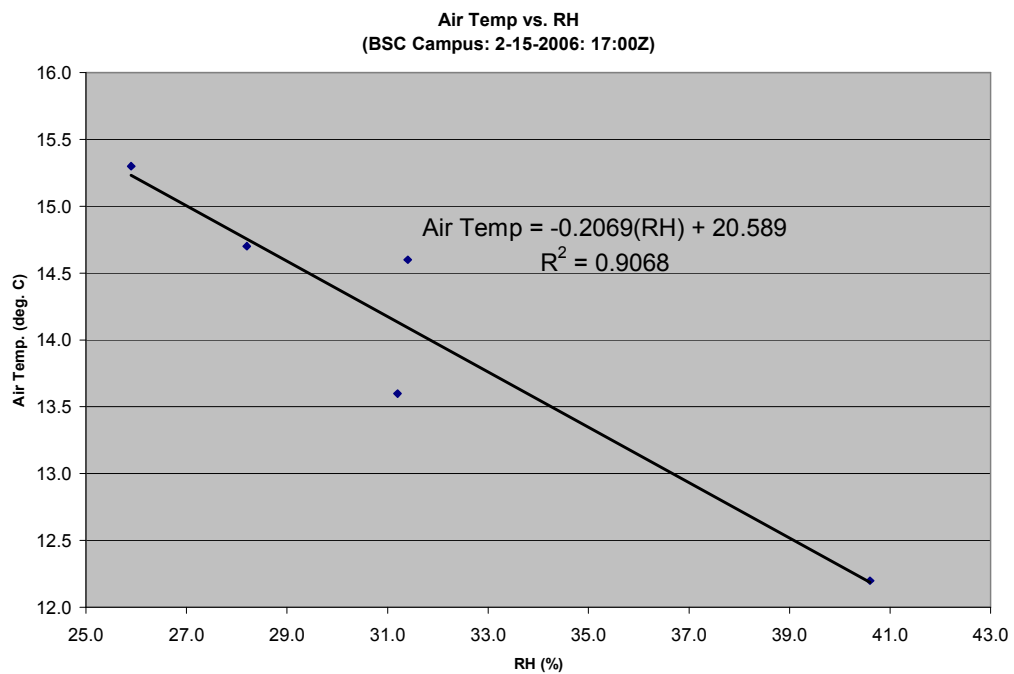
Sensor Response Time for 90% of Total Range: 60 sec typical

## Digital flip-stick thermometer (for soil temps)



- Range is -58 to 572°F and -50 to 300°C ·
- Resolution is 0.1° from -20 to 200; 1° outside this range ·
- Accuracy is ±0.3°C or ±1°C

SAMPLE of GRAPH created with EXCEL:



### **(3) Global Climate Change Assessment [Group Presentations]**

Goal: presenting the Current Facts and Understanding of the Intergovernmental Panel on Climate Change (IPCC)

Four groups are assigned to report on the following sections of the IPCC report (2001 or 2007):

- 1) Examining the recent and distant past record of climate change
- 2) Human and natural causes of climate change
- 3) Future scenarios (forecasts) of climate change
- 4) Mitigation strategies (emissions control and/or alternative energy)

After each team presents the facts in Project I (first half of semester), you will be asked to debate issues yet to be determined for Project II (second half of semester). Some debatable questions might include:

- 1) Where and when has climate changed over the recent and distant past?
- 2) How well can scientists separate "human" from "natural" causes of climate change?
- 3) What are the future predictions of global climate change and are forecasts reliable enough?
- 4) Can all people adapt to the scenarios of future climate changes? How can present and future civilizations prepare for and reduce causes and adapt to the effects of climate change?

Objective 1: Collect and summarize the evidence provided by the IPCC report:

See: <http://www.ipcc.ch/>

Objective 2: Each group should produce a single sheet of paper (front and back is OK) to summarize your findings. You are required to send this to your instructor (via email or digital drop-box) prior (2 days) to the date of your presentation (see syllabus). These will be posted on Blackboard so that other groups can review your findings prior to the date of the presentation. The instructor can make color copies for handing out upon request.

Objective 3: Each group should come up with one (1) question to ask each of the other three groups about the material presented in their summary sheet.

You may use PowerPoint, posters, overheads etc... to present your findings.