SMS-204: Integrative marine sciences.

Lab 4, Heat and temperature.

Today we will look at several aspects of heat and temperature.

In all of these experiments think about heat and how heat is moving (heat flux). Is it radiative, convective or conductive heat flux that takes place?

**Station 1**: Change of boiling point of water with pressure.

Material: Pyrex bottle, boiling water.
Carefully pour boiling water into a bottle.
Seal the bottle, invert over a sink and pour cold water over it.
Observe what happens.

Try to explain the observation given that:
1. For gas, pressure is proportional to its temperature.
2. The boiling point of water decreases with decreasing pressure.

Can you relate it to pressure cookers?
Fig. 1: In this activity container in which water has just boiled (in the pyrex container heated on the left) is either: 1. cooled in cold water (the top where the air is) or 2. attached to a pump which reduces the pressure within. In both cases the reduction in pressure (as air of fixed volume cools its pressure drops, $PV=nRT$) is associated with decrease in the boiling point of water resulting in boiling water. In a pressure cooker, the pressure increase due to the temperature rise of the air increases the boiling point providing a higher temperature in which to cook.

**Station 2. Why is it colder in the winter?**
Material: inflatable globe, flash light.

Place a flashlight at a given distance from the ball equator and shine it. Keep the light level and raise the light such that the region near the pole is illuminated.

Where is the amount of radiative flux per unit area larger?
How are your results related to the changes in temperature between morning and noon, seasonality, etc.?

It turns out that the change in area illuminated varies like the cosine of the angle between the local zenith (a line perpendicular to the globe at the point the light illuminates) and the flashlight. Is it consistent with your observations?
Figure 2. The beam footprint of a flashlight changes as function of latitude similar to solar radiation. On the Earth this results in an uneven distribution of solar heating on the globe.

**Station 3.** Water thermometer.
Materials: bottle, one-hole stopper, long glass tube.
Fill the bottle with water so it extends to 1/3 of the length of the straw above the stopper. Put the bottle in a container of hot water. Mark the position of the water. Place the bottle in ice water. Mark the position. You have made a thermometer.

Do you think your thermometer calibration will be applicable to Mt. Everest?

**Station 4.** Thermal sensitivity.
Materials: 3 containers with hot, ice-cold, and room-temperature water.

Place both hands in room-temperature waters for 30s.
Next place one hand in the hot water and the other one in the ice water for about a minute.
Put your hands back in the room-temperature water.
How does the room-temperature water feel to each hand?
What does it say about our heat-sensing capabilities?

*Fig. 3. This activity demonstrates that our sense of temperature is relative and depends on our previous temperature exposure (and thus temperature).*
Station 5. Conduction

Materials: 3 types of material at the same temperature – wood, metal and cloth

Which type do you think will feel colder?

Briefly place a hand on each type of material. Which type feels coldest? Which type feels warmest?

Given that they are at the same temperature, why do they feel different?

Fig. 4. Materials that are good conductors feel colder to the touch because the transfer the heat from our body away keeping the area we touched from heating up to our body temperature. Poor conductors heat locally and thus do not feel cold.

Station 6. Convection.
Materials: convection set-up, color.

Put ice in one basin and warm water in the other. What direction of flow would you expect for the water in the convection setup? Add drops of dye to the two columns and observe whether they agree with your prediction.
Fig. 5. fluid that is warmed rises and fluid that is cooled sink (due to density differences) resulting in a circulation of fluid in the pipe. The same circulation can be achieved by only cooling or warming one of the sides from below or cooling one of the sides from above (similar to the oceans thermohaline circulation).

**Station 7. Radiometer.**
Put the radiometer away from a light source. Put it near a light source. Explain how a radiometer works (think about pressure, temperature, and gas).
Fig. 6. The radiometer’s wings are painted black and white on their opposite faces. Air near the black sides expands as the black side is warming due to absorption of light. The white side heats less resulting in a pressure difference that causes the air to flow. The air pushes the wings resulting in their motion.

Station 8. Absorption.
Two thermometer one immersed in a shiny tin can the other in a black one. The same light source shines on both. Why is there a difference in temperature among the cans?

Will the temperature increase for ever or will a steady state in temperature be eventually reached?

What will be the balance of heat-fluxes after a very long time?
Fig. 7 and 8. Similar cans one which is black the other shiny warm up very differently when shined upon due to the absorption by the black can. The can reach an equilibrium temperature when the gain of short wave radiation equals the loss to long wave radiation and heating of the surrounding air through conduction.
Station 10. Sling psychrometer.
A sling psychrometer is a device allowing us to measure relative humidity by measuring the temperature of a thermometer wrapped in a wet cloth (the wet bulb) and a dry one.

How do you expect the temperature between the two to vary as function of humidity?

Why should there be a difference between the two readings?

Swing the psychrometer for 20s and then note the difference in temperature between the two thermometers. Use a table to compute the relative humidity in the lab. How accurate do you think this method is?

Reference:

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