Written Homework #1 Key
NATS 101, Sec. 13
Fall 2010

40 Points total
10 points per graded question
10 points for attempting all questions.

1. What is the difference between mass and weight?

Mass is an intrinsic property of a substance that is the same regardless of location. Weight is the force of an object due to gravitational acceleration (mass of an object multiplied by gravitational acceleration). Thus, the weight of an object can vary depending on the gravitational acceleration at a given location.

2. What does a mercury barometer measure? Describe this device and explain how it physically works.

Barometers measure air pressure. A mercury barometer consists of a long, vertical tube partially filled with mercury. At the top end, the tube is sealed and is a vacuum. At the bottom end of the tube, the mercury is exposed to air. The weight of the column of mercury is opposed by the pressure of air on openings at the base of the instrument. Changes in air pressure will result in increasing or decreasing mercury column height in the tube, which can then be measured.

3. Describe how atmospheric temperature changes going vertically upward toward outer space. How do these changes related to the various levels of the atmospheres (i.e. the "spheres") and the atmospheric lapse rate?

The levels of the atmosphere are defined by whether or not the atmospheric temperature is increasing or decreasing with height, or the atmospheric lapse rate.
Troposphere (surface to 10 km): Temperature decreases with height troposphere decreases to
Stratosphere (10 km to 50 km): Temperature increases with height (due to UV absorption by ozone).
Mesosphere (50 km to 90 km): Temperature decreases with height
Thermosphere (90 km to 500 km): Temperature increases with height (due to ionization of gases).
Exosphere (beyond 500 km): Basically outer space.

4. Given that mean sea level pressure is defined to be 1013 mb, what would the air pressure be at the top of Mt. McKinley (Denali) in Alaska, the tallest point on the North American continent at 6194 m? Show your work.

Using the equation for pressure variation as an exponentially decaying function of height, as presented in class lecture:

$$P = P_{MSL}\ X\ 10^{\left(\frac{-6.194\ km}{16\ km}\right)}$$

$$P = (1013mb)\ X\ 10^{\left(\frac{-6.194\ km}{16\ km}\right)}$$

$$P = 466mb$$

P_{MSL} = mean sea level pressure = 1013mb
P = Final pressure at the top of the mountain.

5. Define and differentiate between weather and climate. Give two examples of each

Weather is conditions at a given time and place. Climate is the statistical characteristics of weather over time (note that climate is not just the mean of weather!). Examples of weather include a tornado or hurricane. Examples of climate include average July high in TUS or the change in global temperature over 100 years

6. Decode the following surface meteorological observation for Pocatello, Idaho, (PIH) taken at the same day as the Colorado snowstorm case discussed in Lecture 3.

PIH: Wind 315°(northwest)@3-7kt; sky obscured; visibility 1/2sm with freezing fog, or fog with showers; temp/dewpoint(°F) 17/15; pressure 1037.3mb

7. Describe the three mechanisms of heat transfer and how they are illustrated in the example of a boiling pot of water on a stove.

Conduction: heat transfer by molecule to molecule contact. Occurs where the coils on the burner meet the pot.
Convection: heat transfer by mass movement of molecules, in fluids or gases. Occurs in the water, as illustrated by the rising plumes with the dye.
Radiation: heat transfer though electromagnetic waves that does not require the presence of molecules and can occur in a vacuum. Explains the heat felt on your hand near the side of the pot.

8. Explain the concept of specific heat. How does the specific heat of water compare to other common substances and why is this important?

Specific heat is equal to the amount of energy required to raise a given amount of matter per unit of temperature. The specific heat of water is higher than most other substances in our environment, like soil for example. Thus bodies of water heats and cools more slowly than land, moderating climate.

9. Suppose that 500 g of water vapor condense to make a cloud. Given a latent heat of condensation of 600 cal/g, how much heat is released to the air? If the total mass of the air is 100 kg, how much warmer would the air be after condensation? (Hint: Use the specific heat of air in Table 2.1 in the textbook). Show all work. Based on your answer, describe how phase changes of water are related to atmospheric energy, such as in phenomena like thunderstorms and hurricanes.

Given: Mass of water vapor condensed = m = 500g
Latent heat of condensation = L_C = 600 cal/g
Total mass of air = M = 100kg
To find: Heat released in air E
Change in temperature of air ΔT
Formula: Heat released in air = mass of water vapor condensed times the latent heat of condensation

$$E = M * latent\ heat$$

Change in temperature = energy released in air / product of total mass of air and the specific heat capacity for dry air

$$\Delta T = \frac{\frac{E}{M}}{C}$$

Solution: E = 500g * 600cal/g = 300,000cal
C = 0.24 cal/g degree C (from Table 2.1)
m = 100kg * 1000 = 100,000g

$$\Delta T = \frac{\frac{300{,}000cal}{100{,}000g}}{\frac{.24cal}{g}} * {}^{\circ}C$$

$$\Delta T = 12.5^{\circ}C$$

This amount of energy transferred to the atmosphere provides a source of heat to the atmosphere, thus providing the necessary warming for convection to happen, such as occurs in a hurricane or thunderstorms.

10. Assuming a normal human body temperature of 98.6 ºF, what is the wavelength of maximum radiation emission from your body? In what part of the electromagnetic spectrum does this fall? Show your work. What radiation law must be applied to solve the problem?

Given: Body temperature = T = 98.6^{o}F

To find: Wavelength of maximum emission radiation λ_{max}

Formula: We use Wein's law to solve the problem –

The wavelength of the maximum radiation emission from a body is inversely proportional to the temperature and proportionality constant is given as 3000umK.

$$\lambda_{max} = \frac{b}{T}$$

Solution: The formula requires the temperature to be measured in Kelvin scale. Hence, the first step is to convert the temperature into Kelvin scale.

^{o}C = 5/9 (F - 32) = 37 ^{o}C

K = ^{o}C + 273 = 310K

$$\lambda_{max} = \frac{(3.0 * 10^{3} um \cdot k)}{310k}$$

$$\lambda_{max} = 9.7um$$

This is infrared

11. Following for the previous question, how much radiant energy per unit area (W m^{-2}) does your body emit? What radiation law must be applied to solve this problem?

Given: Body temperature = T = 98.6°F

To find: Radiant energy per unit area emitted by the body E

Formula: The radiant energy emitted by a body per unit area is directly proportional to the fourth power of the body's temperature as per the Stefan-Boltzmann law of radiation. The proportionality constant is given by the Boltzmann's constant σ = 5.67 * 10^{-8}W/m^2K^4.

$$E = \sigma T^4$$

Solution:

$$E = 5.67 * \frac{10^{-8}\,w}{m^2K^4} * (310K)^4$$

$$E = \frac{523w}{m^2}$$

12. Why are the shortest wavelength, highest frequency electromagnetic waves, like gamma or x-rays, the most dangerous type of radiation?

Gamma and X-rays are the most dangerous types of radiation as they have the ability to penetrate deep into a substance and break down molecular bonds, including those of genetic material (DNA/RNA). Thus they can cause harmful genetic mutations, or, in the case of gamma rays, destroy all life in an instant.

13. Explain how the earth's atmospheric greenhouse effect works. What atmospheric gases are primarily responsible for the greenhouse effect and why?

The components of our atmosphere are largely transparent to incoming solar (shortwave) radiation. Earth's IR outgoing terrestrial (longwave), or infrared, radiation however is partly absorbed by certain gasses in the atmosphere such as CH_4, CO_2, H_2O because of their particular molecular structure. These gasses then reradiate energy in all directions. When some of the emitted longwave, infrared radiation from these gasses reaches the earth's surface, the surface equilibrium temperature of the earth increases, keeping surface temperature warmer than it otherwise would be.

14. Why is the sky blue?

The sky is blue because the air molecules selectively scatter the shorter wavelengths of visible light more effectively than longer wavelengths.

15. Describe how clouds affect the earth's energy budget in the solar (shortwave) and terrestrial (longwave) part of the radiative spectrum.

Clouds reflect some solar energy, absorb some and transmit some. They also absorb and re-emit IR radiation. The exact effect on the earth's energy budget depends on when, where, and what type of clouds form. For example clouds at night tend to warm the surface of the Earth because they emit infrared radiation to the surface, while clouds during the day tend to cool the planet because they reflect solar radiation.