**Homework Assignment 1 Due 1/23 (4pm)**

**(Energy)**

**Problem 1.** An 8cm3 block of ice at temperature T = -10°C sits in microwave. You turn the microwave on high, and wait. If the microwave delivers 500W of power, how long would it take to vaporize the ice cube into a 150°C gas. Take cice = 2.1 kJ/kg°C, cwater = 4.18 kJ/kg°C, cwater vapor = 2.0 kJ/kg°C; Lf = 333 kJ/kg, and Lv = 2256 kJ/kg. And finally take the density of ice to be ρ = 920 kg/m3.

The mass of our cube is:



And so the change in energy of the cube will be:

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We can get the time from P = ΔE/Δt → Δt = ΔE/P, so:



**Problem 2.** In order to escape Earth’s gravitational field, an object would have to have a velocity of about 11km/s. This applies to rockets and gas molecules equally. If a gas molecule’s average speed is greater than 10% of the escape speed, then there is a high enough chance it will acquire enough speed, via random collisions, to exceed the escape velocity every once and a while (and once is enough). (a) What is the average speed of a He molecule at the typical temperature T = 300K. What does the tell you about the likelihood of finding He gas in our atmosphere? (b) What is the average speed of a N2 molecule? (c) Of an O2 molecule? (d) of an H2O molecule (water vapor)? Should we be worried about losing all of our air, and our oceans (to evaporation)?

Recall,



So,

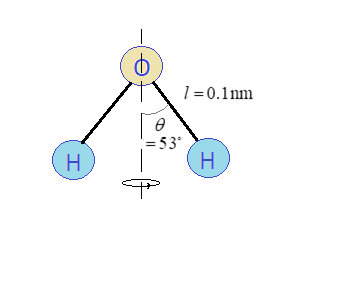


Since this is greater than 10% the escape velocity, we may expect that whatever amount of He gas initially present in our atmosphere is long gone. But the speed of O2, N2, H2O are:



These are less than 10% the escape velocity, so we’re OK. Yay!

**Problem 3.** A water vapor molecule (H2O) floats in the atmosphere at temperature T = 25°C. (a) What is its moment of inertia about the axis shown? (Perhaps you’ll recall that I = Σmr2 where m is mass, and r is distance of mass from the axis of rotation; perhaps you won’t recall) (b) Estimate the molecule’s frequency of rotation about this axis (also recalling that f = ω/2π). (c) What is the total energy of our water vapor molecule? (d) If we fill a 1000cm3 balloon with water vapor to a pressure P = 50 kPa, what will be the gas’s total energy?





From the equipartition theorem, we have:



From which it follows that:



(that’s 2.2 trillion times per second!) The total energy of the molecule is:



Energy of all the molecules is, recalling PV = NkBT:



**(Entropy)**

**Problem 4.** What is the overall change in entropy of the block of ice in problem 1?

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**Problem 5.** Suppose you have a random gas kept in a container of volume V = 0.02m3, pressure p = 3atm, at room temperature T = 27°C. Then you open the container and let it expand into a 10m×10m×3m room. What will be its change in entropy?



**(1st and 2nd Laws of Thermodynamics)**

**Problem 6.** A 50g ice cube at -20°C is placed in a 1.5kg aluminum bucket whose initial temperature is 30°C. Suppose ice’s specific heat is cice = 2kJ/kg∙C, and Al’s specific heat to be cAl = 0.92 kJ/kg∙C. What will be the final equilibrium temperature? What will be the overall change in entropy for this situation?



And,



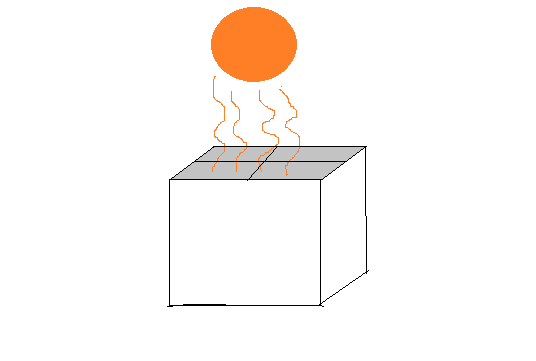
**Problem 7.** Suppose



**Problem 8.** Sunlight is incident on asphalt at an angle of 20° with respect to the vertical. The sunlight’s intensity is 1250 W/m2, and 8% of it is reflected from the surface. The surrounding air temperature is about 25°C. What temperature will the asphalt equilibrate to, assuming the ashphalt loses heat mostly through convection, and gains through solar radiation? You may take the convection coefficient to be 15 W/m2°K.



**Problem 9.** Suppose a cubic shed has a window for a roof, and is under direct sunlight. Let the sunlight intensity be I = 1200 W/m2 and 10% be reflected from the window. The walls and floor of the shed are made of wood, with thermal conductivity k = 0.12 W/m∙K and thickness 5cm. The thermal conductivity of the window is about 0.95 W/m∙K, and has thickness 1cm. Finally the ambient air temperature is 20°C. What will be the equilibrium temperature of the shed? You’ll be considering solar radiation and conduction (through all six surfaces of the shed) here.





**Problem 10.** Earth is about 1.5×1011m from the Sun, and the intensity of sunlight here is about 1200W/m2. Neptune’s mean distance from the Sun is about 4.5×1012m. (a) What do you expect sunlight’s intensity to be there? (b) assuming that Neptune’s temperature is maintained by the balance between solar and thermal radiation, what do you expect it’s average temperature to be? You may assume Neptune radiates heat across its entire surface, and take the ε’s to be 1.

Sunlight’s intensiity would be:



And then,



**Problem 11.**  You and your friend through snowballs at each other – very gluey snowballs designed specifically for this problem. You throw your m1 = 1kg snowball with a speed v1 = 28m/s; your friend throws her m2 = 2kg snowball with a speed v2 = 16m/s in the opposite direction. They collide and stick together. Assuming their initial temperature is T = 0C, and it’s a T = 0C day, how much of the snow melts?

First we must use conservation of momentum,



And then we use the 1st law:

