1 Three ideas for the term project

Read the description of the term project on the class website at "Introduction to term project". Identify three (3) subjects that you find interesting/intriguing (for example, solar energy, exoplanets, ...). Within each subject, pose a question that might have an interesting quantitative answer: "Since it requires energy to make a solar panel, how long does it take to recoup that energy?", "How far away could we see an Earth-like planet orbiting a Sun-like star?" ... You should turn in 3 different subjects and 3 different quantitative questions (quantitative means "quantities that can be calculated and/or measured")

Let your mind wander as broadly as possible. Subjects and questions are not restricted to the topics taught in PH315. During this exploratory stage, be bold and daring; you are not committing yourself to solve all 3 questions. To spark your imagination, there is a list of ideas on the class website. The instructor will read your ideas and give you feedback. Whenever possible, the feedback will point you towards a coarse-grained model that is helpful for answering your question. Use the feedback to help decide which question you will develop further (or whether you need to go back to the drawing board).

2 Multiplicity of an ideal gas

(a) **(T3M.7)** The multiplicity of an ideal monatomic gas with N atoms, internal energy U, and volume V turns out to be roughly

$$\Omega(U, V, N) = CV^N U^{\left(\frac{3N}{2}\right)} \tag{1}$$

where C is a constant that depends on N alone. Use this expression, together with the fundamental definition of temperature, and they fundamental definition of entropy, to find U as a function of N and T for an ideal gas.

(b) **(From the GRE PhysicsSubject GR0177, given in 2001)**
Note 1: The irreversibility of this process tells you that entropy must go (up or down?).
Note 2: The gas constant, R, is equal to Avagadro's number times k_B.

47. A sealed and thermally insulated container of total volume V is divided into two equal volumes by an impermeable wall. The left half of the container is initially occupied by n moles of an ideal gas at temperature T. Which of the following gives the change in entropy of the system when the wall is suddenly removed and the gas expands to fill the entire volume?

(A) $2nR\ln 2$

(B) $nR\ln 2$

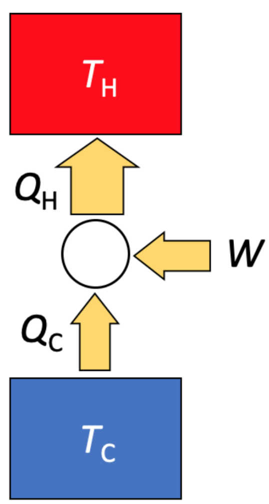
(C) $\frac{1}{2}nR\ln 2$

(D) $-nR\ln 2$

(E) $-2nR\ln 2$

3 Heat Pump

The diagram shows a machine (the white circle) that moves energy from a cold reservoir to a hot reservoir. We will consider whether a machine like this is useful for heating a family home in the winter when the temperature inside the family home is T_{H}, and the temperature outside the house is T_{C}. To quantify the performance of this machine, I'm interested inthe ratio Q_{H}/W, where Q_{H} is the heat energy entering the house, and W is the net energy input in the form of work. (W is the energy I need to buy from the electricity company to run an electric motor). Starting from the 1st and 2nd laws of thermodynamics, find the maximum possible value of Q_{H}/W. This maximum value of Q_{H}/W will depend solely on the ratio of temperatures T_{H} and T_{C}.



Sensemaking: Choose realistic values of T_{H} and T_{C} to describe a family home on a snowy day. Based on your temperature estimates, what is the maximum possible value of Q_{H}/W?

4 Thermal energy in the earth's atmosphere

Thermal energy is stored in all materials on Earth, including the air, water and rocks. The air is composed mostly of diatomic molecules such as N_2 and O_2.

(a) Use Google to look up the mass of the earth's atmosphere. Now, exercise some skepticism and make sure that Goggle's answer is consistent with other facts about the earth: Air pressure at sea level is about 100 kPa and the radius of the earth is about 6400 km. The air pressure at sea level (force per unit area) is caused by the downward force of gravity acting on the atmosphere directly above a unit area. The thickness of the atmosphere is much much less than the radius of the earth. Give your argument supporting or refuting the internet's value for the mass of the earth's atmosphere.

(b) We know that between 1955 and 2010, the temperature of the top 2000 meters of the ocean rose by about 0.05 C. Given this fact, assess the validity of the following statement:

> "If the same amount of heat that has gone into the top 2000 meters of the ocean between 1955-2010 had gone into the lower 10 km of the atmosphere, then the atmosphere would have warmed by about 20°C (36°F)."

Is this statement reasonable, or ridiculous? Show your calculations that support your conclusion. Your starting assumptions will include the specific heat capacity of air and water, and a reasonable guess regarding the fraction of the earth's surface that is covered with ocean.