Homework 3

Due Friday Jan 27 at 5pm. Hand in to Paul Emigh.

1. Degrees of freedom that influence the energy

For a molecule of O_2 in the gas phase at room temperature, calculate (i) the average magnitude of the center-of-mass velocity, (ii) the average angular velocity for rotation about an axis perpendicular to the bond axis. The distance between the oxygen atoms is 0.121 nm. Angular velocity is typically expressed in radians per second.

2. Order of magnitude: Energy usage

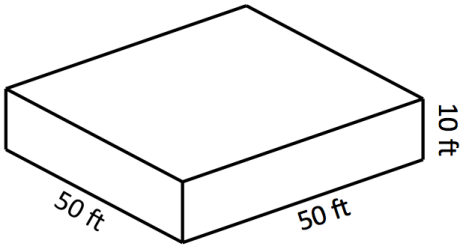
David MacKay estimates that taking a hot bath uses 5 kWh of energy. Verify his order of magnitude estimate by using the appropriate relationship between temperature and the internal energy of water.

3. Order of magnitude: The earth's climate

Between 1955 and 2010, the temperature of the top 2000 meters of the ocean rose by about 0.05 C. Use your knowledge of the internal energy stored in liquid water, the internal energy stored in nitrogen gas, and your skills at order of magnitude calculations, to access the validity of this 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 10km of the atmosphere, then the Earth would have seen a warming of about 20°C."

4. Heat flow through a building envelop



The diagram above shows a simplified model of a family home. The temperature inside the "box" is 68 F (20 C) and the temperature outside all six sides of the box is 41 F (5 C).

a) Assume that all six sides are insulated uniformly with R20 insulation (thermal resistivity 20 $ft^2 \cdot °F \cdot hr/Btu$ = 3.5 $m^2 \cdot °C/W$). What is the rate that thermal energy leaves the house? How much energy will be required to heat this house for one day?

b) Repeat the calculations you did in part a, but make the floor and ceiling R40 and the walls R10.

Note: An energy efficient house in the Pacific Northwest has R38 insulation in the ceiling, R30 insulation under the floor, and R10 for the wall system. Energy efficient windows are R3.

5. Changes in pressure and volume

a) A monatomic ideal gas with initial pressure of 80 kPa is confined to a cylinder with a volume of 600 cm^3. We then compress the gas isothermally until its volume has decreased to 450 cm^3. What is the pressure now?

b) A monatomic ideal gas with an initial pressure of 60 kPa is confined to a cylinder with a volume of 600 cm^3. We then compress the gas adiabatically until its volume has decreased to 450 cm^3. What is it's pressure now?

c) An ideal gas is constrained to follow the three step cyclic process shown in the graph below. Specify the sign of Q, W, and ΔU for each step of the process. What is the net work flowing into or out of the gas for the entire cyclic process (be sure to give the correct magnitude and sign)?