Homework #4

Due Friday Feb 3 at 5pm. Hand in to Paul Emigh (office 491 Weniger).

1. Preparing for the term paper

Propose a topic for your term paper. Suggest one graph and one original calculation that would satisfy the assignment guidelines.

There are many places to looks for topic ideas. Here are a few resources that have excellent physics content:
- David MacKay's book "Sustainable Energy Without the Hot Air" (free download)
- "Phyiscs for Future Presidents" ($10 paperback)
- David Archer's book "Global warming: Understanding the forecast" ($30, used text book from Amazon).

2. Heat conductivity

Using technically accurate physics language, describe why a wood block at 15 deg C feels warmer to the human touch than a metal block at 15 deg C. Note that body temperature is 37 deg C.

3. The ideal gas law

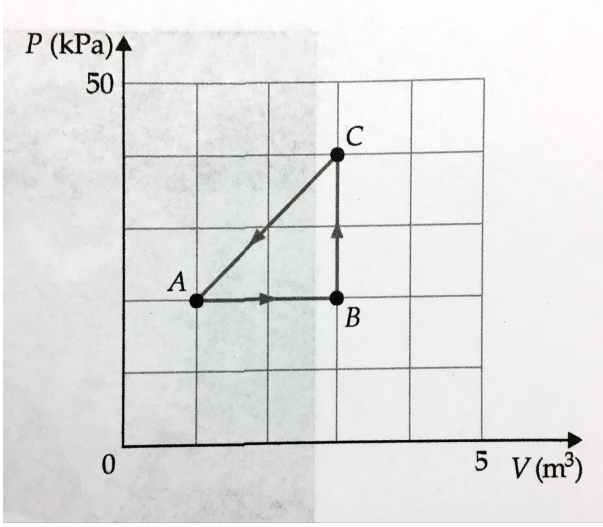
Use the equipartition theorem to derive the ideal gas law.
If you need some hints, watch this video:
https://media.oregonstate.edu/media/t/0_j9ocjq3y

4. 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 diatomic 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 (no heat goes in or out) 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)?



5. Carnot efficiency

In class we calculated the coefficient of performance of a heat pump that utilizes the Carnot cycle. Do a similar analysis to find the efficiency of an engine that utilizes the Carnot cycle. Express the efficiency in terms of T_h and T_c.

6. Formula 1 racing innovation

The latest Prius hybrids have a 40%-efficient combustion engine (better than typical older cars). Formula 1 race cars are pushing the combustion engine efficiency even further. The current record (2016) for the Mercedes F1 race car is 47%. Assuming that the air in the cylinder of the engine is initially at 20 C, estimate the maximum temperature reached by the air.

7. Electricity generation and heat pumps

Electrical energy (and heat) is output from a coal-burning power station. The electricity is made by heating/cooling a working gas using T_h = 200 C and T_c = 5 C. The electricity is sent to nearby buildings where it is used to run high-performance heat pumps. The outside air temperature is 5 C. The temperature inside the buildings is 20 C. Assume that both the power station and the heat pump are operating at the themodynamic efficiency limit.

a) Calculate the following ratio:

$$\frac{\text{Heat energy pumped into the buildings}}{\text{Chemical energy consumed by the power plant}}$$

b) If our goal is to minimize CO_2 emissions, is it better to burn the coal in our houses (turning nearly 100% of the chemical energy into heat), or burn the coal in power stations and use an ideal heat pump?