General Advice Problems are divided into S(mall), M(edium) and L(arge). Small problems shouldn’t take you more than a couple of minutes. You should not (generally) need to use calculators - this is an order-of-magnitude class!

More than any other class you’ve taken, process is much more important than the answer. There’s also no right or wrong process in many cases. Thus, be very explicit about assumptions and your thought process (i.e. more text than in a normal problem set). In fact, a good answer will look a lot more like a textbook (or even an essay) than it will a typical problem set. You might even want to type them for legibility if your handwriting is marginal. Also, the more you estimate and the less you look up, the better. Working together is encouraged.

PROBLEM 1 [S] How many trees are there on Earth?

PROBLEM 2 [S] What is the energy density (W/kg) of the Sun compared to that of a mammal?

PROBLEM 3 [M] For a gas, the rate at which all quantities (mass, momentum, temperature) diffuse is basically the same.

a) The diffusivity of momentum is also called the (kinematic) viscosity $\nu$. Write down an expression for $\nu$ in terms of mean free path and sound-speed.

b) The dynamic viscosity $\eta = \rho \nu$, where $\rho$ is the density. Write down an expression for $\eta$ in terms of molar mass, temperature, atomic radius and some fundamental constants.

c) How does the viscosity depend on gas temperature, pressure and molar mass? Does this make sense?

d) Estimate the dynamic viscosity of air at room temperature and pressure.

PROBLEM 4 [M] Compare the energy cost (in J/kg/km travelled) of a load transported by a car with the energy cost of a load transported by a helium-filled blimp. It will help to assume that air resistance is the dominant process, and that both are fully-loaded. Why is the air not crowded with blimps?

PROBLEM 5 [L] The table below gives the boiling temperatures and latent heats of various substances. [NB I know I am using 2 s.f. here, but sometimes we can do better than OOM!]

<table>
<thead>
<tr>
<th>Substance</th>
<th>$T_{boil}$ (K)</th>
<th>$\Delta H_{fus}$ (J/mol)</th>
<th>$\Delta H_{vap}$ (J/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$</td>
<td>20</td>
<td>120</td>
<td>900</td>
</tr>
<tr>
<td>Ar</td>
<td>87</td>
<td>1100</td>
<td>6400</td>
</tr>
<tr>
<td>Xe</td>
<td>170</td>
<td>1800</td>
<td>13,000</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>240</td>
<td>5600</td>
<td>23,000</td>
</tr>
<tr>
<td>H$_2$O</td>
<td>370</td>
<td>6000</td>
<td>41,000</td>
</tr>
<tr>
<td>CH$_3$OH</td>
<td>340</td>
<td>7500</td>
<td>39,000</td>
</tr>
</tbody>
</table>

Table 1: Table of boiling temperatures and latent heats of fusion and vaporization. From *The Planetary Scientist’s Companion* (Lodders & Fegley).

a) Using the lowermost three entries, estimate an average binding energy (in eV).
b) The table shows an approximately linear relationship between $T_{\text{boil}}$ and $\Delta H_{\text{vap}}$. Explain why, and predict the ratio in terms of fundamental constants.

c) What is the actual ratio, and how might you explain the difference to your predictions?

d) Why is the latent heat of fusion less than the latent heat of vapourization?

e) Silica ($\text{SiO}_2$) has a boiling temperature of about 2800 K. Predict its latent heat of vapourization, and also its elastic modulus.

f) Estimate the sound speed of silica vapour.

**PROBLEM 6 [S]** Devise a Small (warm-up) order of magnitude question (and provide an answer).