

Teaching ideas for Topic 3, *Thermodynamics*, AHL

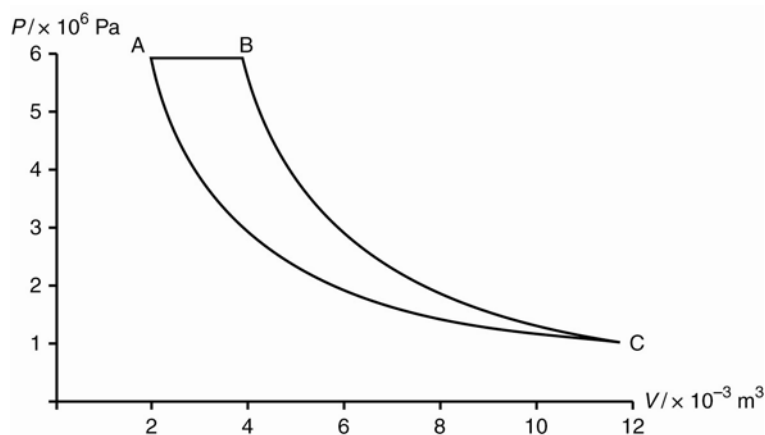
Questions

A number of worksheets are provided for this Topic:

- support questions examine the very basic concepts of the syllabus
- extended questions delve deeper and are equivalent to exam level questions.

Teaching ideas

- In problems students must be careful to see if we are dealing with an ideal gas or some other real substance.
- An ideal gas has no intermolecular energy.
- A real gas may be approximated by an ideal gas only when the pressure is low.
- Practically every problem requires use of $Q = \Delta U + W$ and lots of examples of the first law must be discussed in class.
- In thermodynamic processes it is crucial that students understand that to see if the temperature changes we must look at what happens to internal energy and not Q .
- Adiabatic processes have $Q = 0$ and so a process that takes place fast enough will be adiabatic since there will be no time for any heat to enter or leave the system (and so $Q = 0$).
- The connection between entropy and number of states may be made with simple mathematical examples that students will have seen from their maths classes. For example, consider the problem of arranging books dealing with five different subjects on a long library shelf. Assume that each subject has five books:
 - arranging them such that the five subjects are in alphabetical order and all the books belonging to the same subject are together gives the number of arrangements as $(5!)^5 \approx 2.49 \times 10^{10}$
 - if books belonging to the same subject are together, but the order of the subjects doesn't matter, the number increases to $(5!)^6 \approx 2.99 \times 10^{12}$
 - the number of ways of arranging the books without any constraints is $25! \approx 1.55 \times 10^{25}$.
 - This shows the dramatic rise of the number of arrangements as disorder increases. That is, entropy increases as disorder increases.
- Nothing beats analysing down to the smallest detail a cycle on a pressure/volume diagram, such as the one below that consists of an isobaric expansion, an adiabatic expansion and an isothermal compression back to the original state. The following data are given:
 - number of moles of gas is 4.8
 - change in internal energy during isobaric expansion is 18 kJ
 - work done on the gas during the isothermal compression is 8.3 kJ



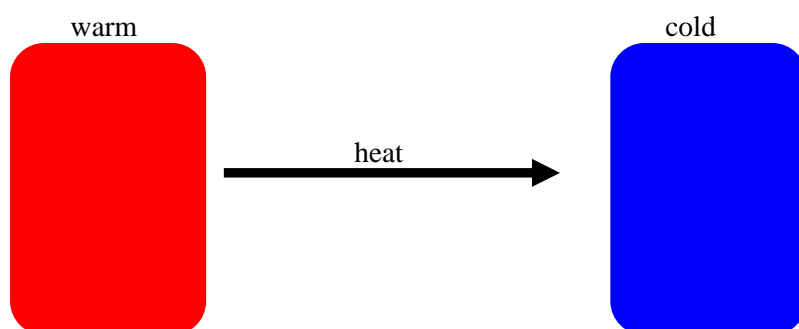
- Questions that can be asked for this cycle include:
 - calculate the initial temperature of the gas (i.e. at A)
 - calculate the temperature after the isobaric expansion (i.e. at B)
 - calculate the heat into the system during the isobaric expansion
 - determine the change in internal energy during the adiabatic expansion
 - show that the net work done by the gas during the cycle is 21.7 kJ
 - suggest whether during a complete cycle, the entropy of the universe has increased, decreased or stayed the same.

Practical activities/ICT

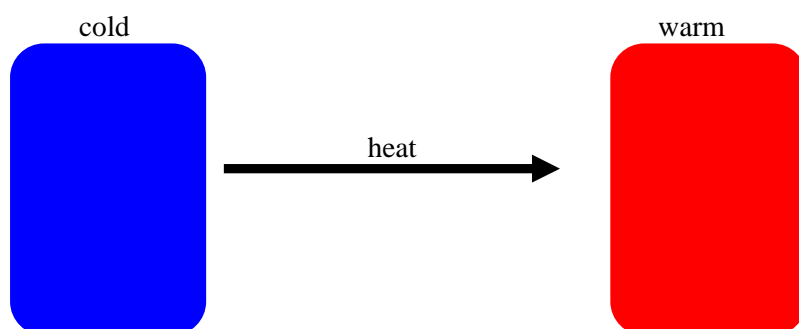
- A classic simulation of gas properties is provided at <http://phet.colorado.edu/en/simulation/gas-properties>
- A simulation in entropy (but not for a Mac) can be found at <http://www.cmth.ph.ic.ac.uk/people/m.foulkes/entropy.html>
- There is a good demonstration of the Maxwell's demon at <http://www.compadre.org/osp/items/detail.cfm?ID=10096>

Common problems

- Students often have difficulty with the concept of entropy, mainly because we define this concept very vaguely and non-quantitatively. It does help to give the formula $\Delta S = \frac{\Delta Q}{T}$ for the change in entropy when an amount of heat ΔQ is transferred in or out of a system. Students can then use this definition to show that heat will flow from the hot to the colder body in order to have $\Delta S_{\text{NET}} > 0$. If the heat flowed from the cold to the warmer body, then $\Delta S_{\text{NET}} < 0$ and the second law would be violated.
Entropy increases



Entropy decreases





Theory of knowledge (TOK)

- This topic has great philosophical dimensions because it deals with one of the most interesting and misunderstood laws of physics, the second law of thermodynamics. The law has been applied to the stock market and human behaviour – is there any justification for doing this?
- The second law of thermodynamics appears ‘different’ from other laws of physics. In what ways?
- What is the basis of the second law of thermodynamics?
- What is the connection between this law and the ‘arrow of time’?
- Why should there be a connection between a law of physics and time?