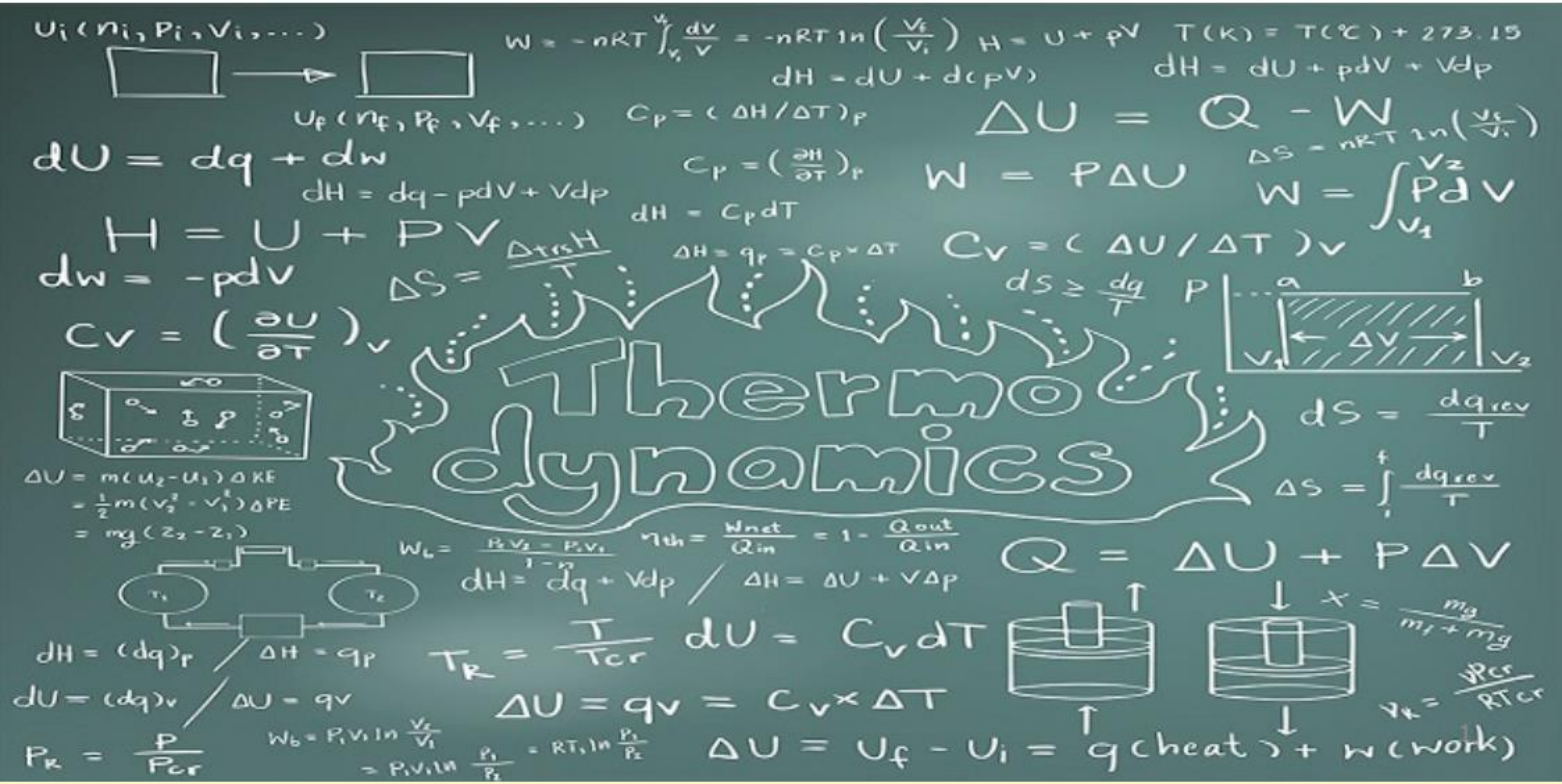
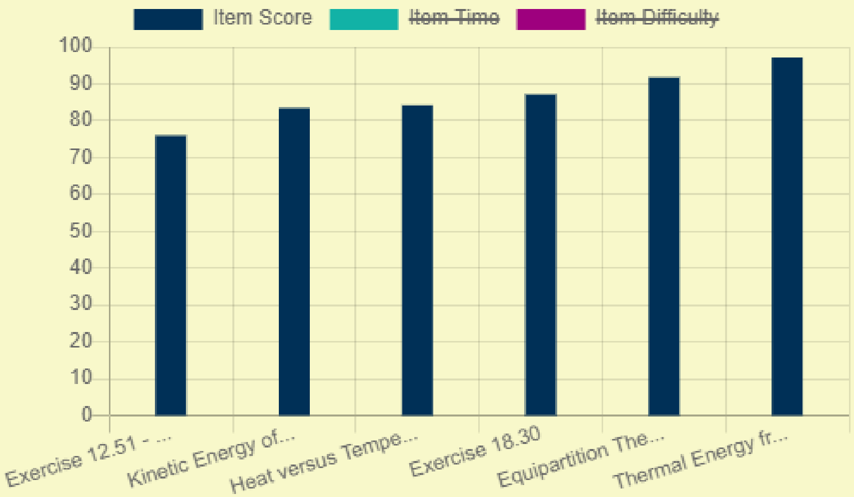
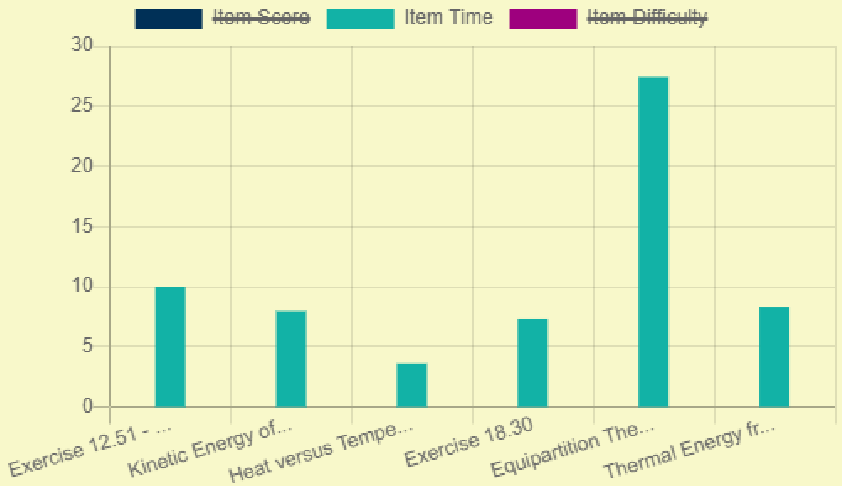
PHYS1013
Energy and Matter

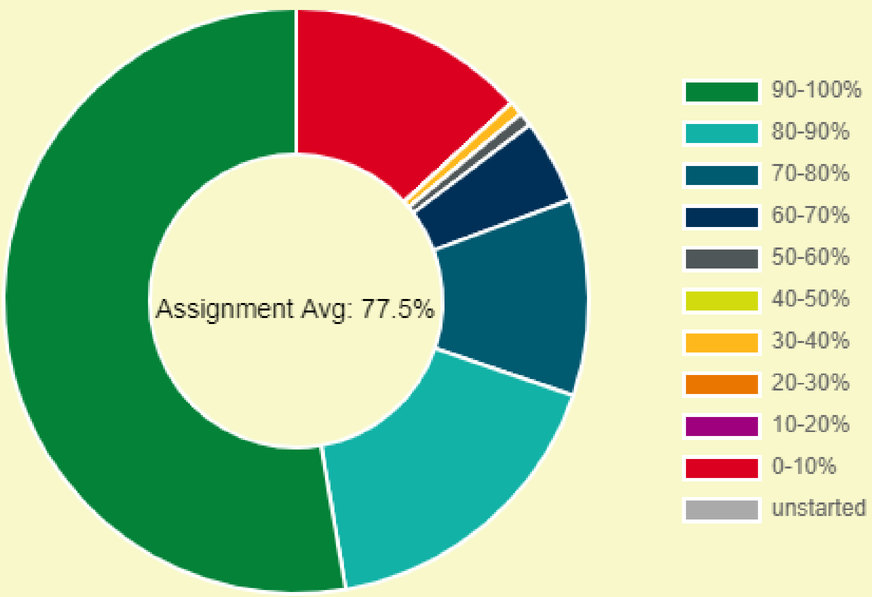


MP Sheet 2 – average score 77.5%

Average time 65 min







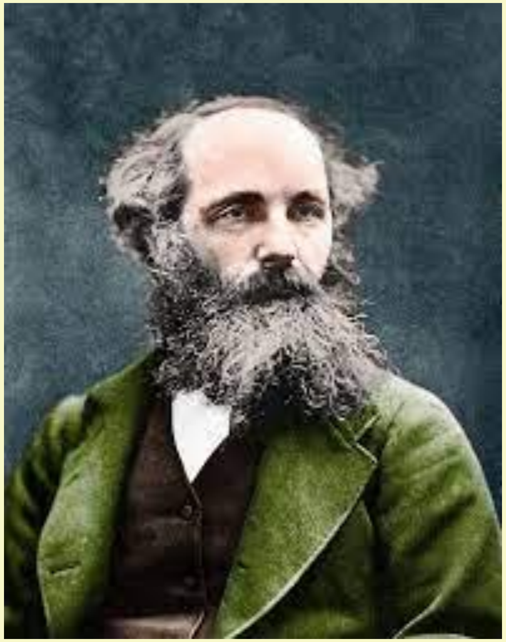
MP3 is not now due until the end of week 6…

Motion of individual atoms summary

- λ is the mean distance travelled by an atom before a collision occurs. In kinetic theory $\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$
- The probability that a molecule travels a distance r without collision is $p(r) = e^{\frac{-r}{\lambda}}$
- For a random walk of N steps, the distance travelled $r = \sqrt{N}\lambda$.
- The kinetic theory predictions for transport coefficients are

  Diffusion coefficient $D \sim \lambda \bar{v}$

James Clerk Maxwell of Glenlair FRS FRSE (1831–1879) was a Scottish[2] physicist and mathematician. In 1865 Maxwell published A Dynamical Theory of the Electromagnetic Field. It was with this that he first proposed that light was in fact undulations in the same medium that is the cause of electric and magnetic phenomena. Maxwell also helped develop the Maxwell–Boltzmann distribution, which is a statistical means of describing aspects of the kinetic theory of gases.



It was unknown how Saturn's rings could remain stable. Maxwell devoted two years to studying the problem, proving that a regular solid ring could not be stable, and a fluid ring would be forced by wave action to break up into blobs. Since neither was observed, Maxwell concluded that the rings must comprise numerous small particles he called "brick-bats", each independently orbiting Saturn. It was considered the final word on the issue until direct observations by the Voyager flybys of the 1980s confirmed Maxwell's prediction.

Maxwell is also known for presenting the first durable colour photograph in 1861 and for his foundational work on the rigidity of rod-and-joint frameworks like those in many bridges.

A collection of his poems was published by his friend Lewis Campbell in 1882.

K/η – our prediction was T independent and equal to 650

Temperature K	η $10^{-6}\,\mathrm{N\,m^{-2}\,s}$	K $10^{-3}\,\mathrm{W\,m^{-1}\,K^{-1}}$	K/η $\mathrm{m^2\,s^{-2}\,K^{-1}}$
100	7.400	8.960	1211
150	11.18	13.85	1237
200	14.65	18.35	1253
250	17.80	22.49	1263
300	20.68	26.38	1276
350	23.34	30.10	1289
400	25.83	33.79	1308
500	30.41	41.13	1352
1000	49.05	74.32	1515

Table 3.2 Experimental measurements of the thermal conductivity and viscosity of oxygen as a function of temperature

T dependence of K/η – we predicted $T^{1/2}$

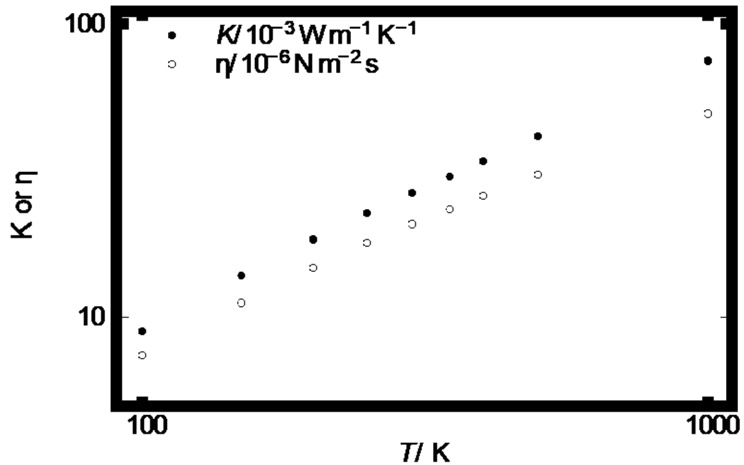


Figure 3.9 Thermal conductivity and viscosity of oxygen as a function of temperature. This is a log-log plot, so both lines should be straight with the same slope if the kinetic theory prediction that *K* and η are proportional to $T_l^{1/2}$ holds.

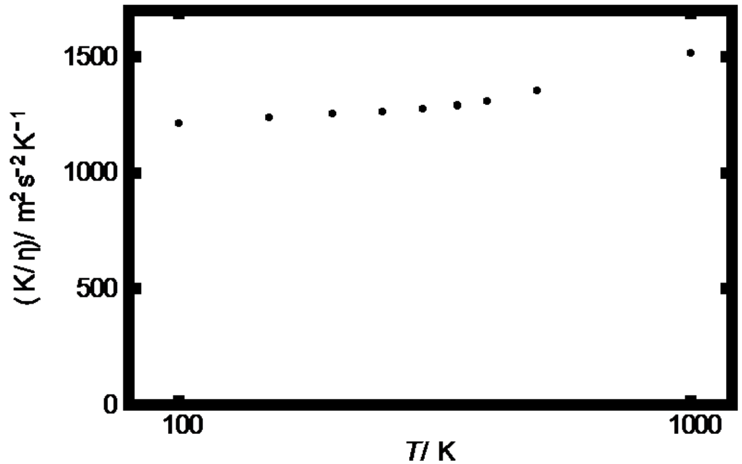


Figure 3.10 Ratio of thermal conductivity and viscosity of oxygen as a function of temperature. This should be a constant if the kinetic theory prediction that *K* and η are both proportional to $T_l^{1/2}$ holds.

Pressure atm	K $10^{-3}\,\mathrm{W\,m^{-1}\,K^{-1}}$
1	26.2
5	26.6
10	27.0
20	27.8
40	29.4
60	31.0
100	34.3

Table 3.3 Thermal conductivity of oxygen as a function of pressure at 300 K

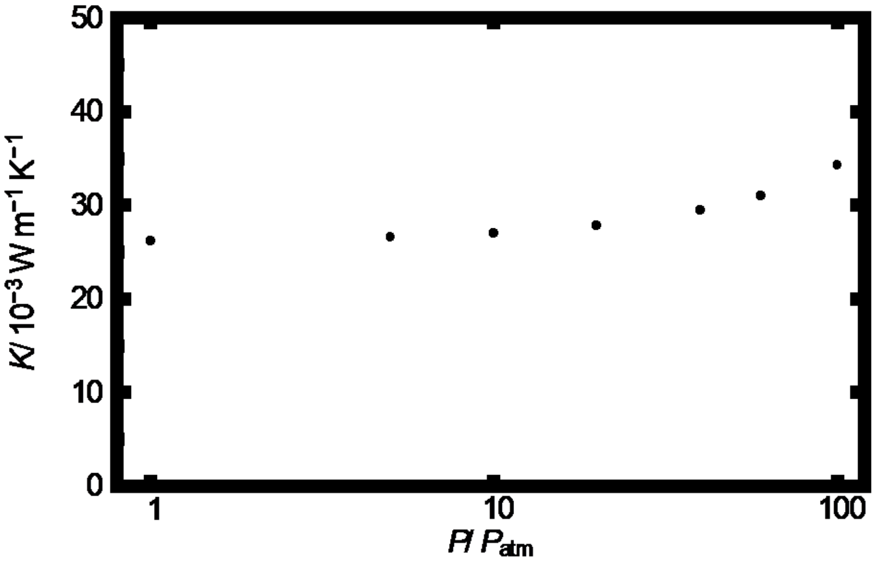
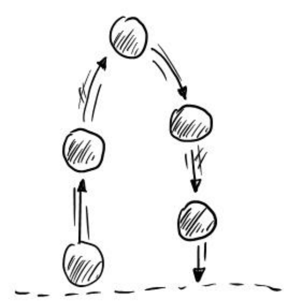


Figure 3.11 Thermal conductivity of oxygen as a function of pressure at 300 K. This should be a constant if the kinetic theory prediction holds.

The Discovery of Energy

Energy conservation is quite odd because energy changes form



eg throwing a ball up:

KE -> PE -> KE - > heat

We teach this from about
age 11 so it seems obvious… it wasn't…

In fact any theory with time independent laws has energy conservation (3^{rd} year)

People got confused eg Carnot

Sous-lieutenant Nicolas Léonard Sadi Carnot (French: 1796 – 1832) was a French mechanical engineer in the French Army, military scientist and physicist, and often described as the "father of thermodynamics." He published only one book, the Reflections on the Motive Power of Fire (Paris, 1824), in which he expressed the first successful theory of the maximum efficiency of heat engines and laid the foundations of the new discipline: thermodynamics.

Caloric Theory

In the 1780s, some believed that cold was a fluid, "frigoric". Pierre Prévost argued that cold was simply a lack of caloric.

Since heat was a material substance in caloric theory, and therefore could neither be created nor destroyed, conservation of heat was a central assumption. Heat conduction was believed to have occurred as a result of the affinity between caloric and matter thus the less caloric a substance possessed, thereby being colder, attracted excess caloric from nearby atoms until a caloric, and temperature, equilibrium was reached.

Carnot, following his father's work on conservation of water in water mills assumed this in his work (we'll come to that).

But Work generates Heat – Duh!

Sir Benjamin Thompson, **Count Rumford**, FRS (German: 1753 –1814) was an American-born British physicist and inventor. He served as lieutenant-colonel of the King's American Dragoons, part of the British Loyalist forces, during the American Revolutionary War. After the end of the war he moved to London, where his administrative talents were recognized when he was appointed a full colonel, and in 1784 he received a knighthood from King George III. A prolific designer, Thompson also drew designs for warships. He later moved to Bavaria and entered government service there.

His experiments on gunnery and explosives led to an interest in heat. He investigated the insulating properties of various materials, including fur, wool and feathers. He correctly appreciated that the insulating properties of these natural materials arise from the fact that they inhibit the convection of air. He then made the somewhat reckless, and incorrect, inference that air and, in fact, all gases, were perfect non-conductors of heat.

Rumford's most important scientific work took place in Munich, and centred on the nature of heat, which he contended in "An Experimental Enquiry Concerning the Source of the Heat which is Excited by Friction" (1798) was not the caloric of then-current scientific thinking but a form of *motion*. Rumford had observed the frictional heat generated by boring cannon at the arsenal in Munich. Rumford immersed a cannon barrel in water and arranged for a specially blunted boring tool.[16] He showed that the water could be boiled within roughly two and a half hours and that the supply of frictional heat was seemingly inexhaustible. Rumford confirmed that no physical change had taken place in the material of the cannon by comparing the specific heats of the material machined away and that remaining.
Rumford argued that the seemingly indefinite generation of heat was incompatible with the caloric theory. He contended that the only thing communicated to the barrel was motion.

Mid-term Responses

OK	8
Good	9
Very Good	23
Excellent	9

Very interesting and well paced
Can be a bit slow at points.

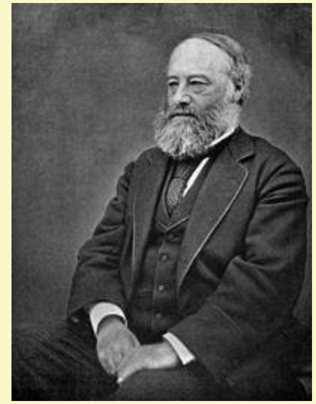
More care over separation on board
I specifically like the use of the chalkboards

More examples a la Mastering Physics
Some more step by step problem examples

Nick's Play List

Consideration by Reef
Fourteen by Wheatus
Rammstein - Keine Lust
Boygenius Not Strong Enough
Pisces- Jinjer
Numbers(I Can Only Count to 4)- Psychostick
Polyphia - Playing God
Ye by Burna Boy,
Na Money by Davido,
Ojuelegba by Wizkid
River or Daisy Mae by Leon Bridges
Welcome to Hell by black midi
I ain't no thief by The Viagra Boys
Car Lights - James Marriott
AC/DC
This is me trying – Taylor Swift
You Wish by Flyana Boss

Wikipedia: James Prescott Joule FRS FRSE (1818 – 1889) was an English physicist, mathematician and brewer, born in Salford, Lancashire. Joule studied the nature of heat, and discovered its relationship to mechanical work (see energy). This led to the law of conservation of energy, which in turn led to the development of the first law of thermodynamics. The SI derived unit of energy, the joule, is named after him.



He heated water both with mechanical paddle wheels and then with an electric current

$$P = I^2 R$$

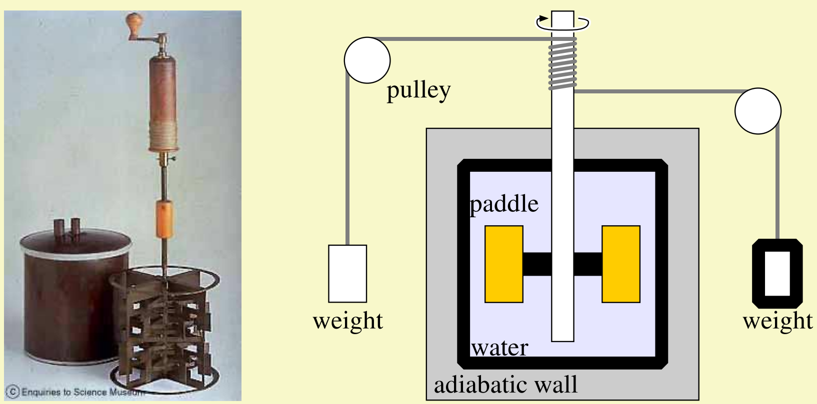


Figure 4.1 Joule's paddle-wheel experiment. Photograph: Science Museum.

"If the state of an otherwise isolated system is changed by the performance of work, the amount of work needed depends solely upon the change effected and not on the means by which the work is performed, nor on the intermediate stages through which the system passes between its initial and final states."

Week 5 (next week)

27/2 Tuesday double lecture slot as usual
No problem classes
No Thursday lecture

So you can revise

Week 6
5/3 Tuesday mid-term test

After the mid-term there will be a down week for lectures - problem classes resume as normal and there is a MP in week 6. Hopefully this will give you the chance to consolidate your work in the term so far.

The last two mid-term tests and solutions are available on blackboard.

The test will cover the first 5 Chapters of the printed notes – material we will have covered by the end of next Tuesday’s lecture.
(this will not include Carnot Engines this year).

You can bring an A4 sheet of written notes in with you…