Week 1 Key Concepts

- **Pressure** is force per unit area ($P = F/A$).

Gases

- **Equation of state for ideal gases:** $PV = NkT$, $P = nkT$, $PV = n_m RT$ where $N = N_A n_m$
- **Transport Laws:**
  Diffusion is caused by density gradient: $\frac{dm}{dt} = -DA\frac{d\rho}{dx}$
  Thermal Conductivity is caused by temeprature gradients: $\frac{dQ}{dt} = -KA\frac{dT}{dx}$
  Viscosity is caused by a velocity gradient: $F_x = -\eta A\frac{dv_x}{dy}$

Liquids

- **Archimedes' principle:** there is an upwards force on an object from the pressure in the water which is precisely equal to the weight of the water displaced (because that displaced water used to be in equilibrium).
- The pressure at a depth d in water is given by $P = \rho dg$ where ρ is the density of water 1000 kg m^{-3}, and g =9.81 m s^{-2}

Solids

- **Young's Modulus**: stress $\propto$ strain $\frac{F}{A} = Y\frac{\delta l}{l}$
- **Bulk Modulus**: contraction under equal surrounding pressure $\Delta P = -B\frac{\Delta V}{V}$
- **Thermal Expansivity**: $\frac{\Delta V}{V} = \alpha \Delta T$

Tutorial problems

1. The total force on a container due to the pressure from a liquid or gas inside is given by

$$\vec{F} = \int_{\text{surface}} P d\vec{A}$$

   Explain what each symbol means and why this is the case.

2. Why do air bubbles rise in water?

3. On average, each person in the UK causes the emission of about 5,000kg of CO_2 per year. This includes the gas you generate directly, for example by driving a car, and that generated on your behalf by power stations and manufacturers. How big a cube of gas would this be at standard temperature and pressure? (STP:273K and 1 atm = 1.01x10^{5}Pa). If it's any consolation this is a third of the value for the US and half the UK value in 1980.

4. How does the heat stored in the air in a room change as the room is heated?

Problem Class Questions

1. The pressure a height h below the surface of a liquid is given by $P = \rho g h$. In 1646, Blaise Pascal is said to have connected a long, thin vertical tube to a barrel. When filled with water, the pressure would cause the barrel to burst.
   (a) Sketch this scenario and explain why the barrel would burst.
   (b) A modern version of this experiment uses a Coke bottle which can withstand $160\,\mathrm{psi}$ (You will often encounter Imperial units in pressure measurements. Please convert to SI). How high would a tube have to be to make this bottle burst?
   (c) What is the difference in water pressure between the top and bottom of a house?

2. A diver 25 m deep in water exhales a 1 cm diameter bubble. What is the diameter of the bubble just before it reaches the water surface? Assume that the temperature of the water is constant, so that the gas in the bubble follows Boyle's law: $PV =$ constant. The density of water is $10^3\,\mathrm{kg/m^3}$.

3. Thermal expansivity and bulk modulus can also be measured for gases. For an ideal gas show that at fixed pressure

$$\alpha = \frac{1}{T}$$

   Show that at fixed temperature

$$B = P$$