1. Dimensional Analysis: By noting that the area of a right-angled triangle can be expressed in terms of the hypothenuse and e.g. the smaller of the acute angles, prove Pythagoras' theorem using only dimensional analysis.

   Hint: Construct a well-chosen line in the right-angled triangle!

2. Dimensional Analysis: Consider an explosion and the expansion of the shock wave. Assuming that the motion of the shock wave is unaffected by the presence of the ground, and that the motion is determined only by the energy E released in the explosion and the density ρ of the undisturbed air into which the shock is propagating, derive a scaling law for the radius R of the shockwave as a function of time t.

3. Van der Waals equation: Show that the use of the Van der Waals equation

$$(P + \frac{a}{V^2})\,(V - b) = NkT$$

   to describe phase transitions in a fluid system leads to the following values of the critical parameters:

$$P_c = \frac{a}{27b^2},\ V_c = 3b,\ NkT_c = \frac{8a}{27b}$$

4. Van der Waals equation: Prove the law of corresponding states

$$(\pi + \frac{3}{\nu^2})\,(3\nu - 1) = 8\tau$$

   where $\pi = \frac{P}{P_c}$, $\nu = \frac{V}{V_c}$, $\tau = \frac{T}{T_c}$.

5. Van der Waals equation: Calculate the free energy F corresponding to the Van der Waals equation of state. Calculate C_V and $C_P - C_V$.

6. Microscopic origin of the law of corresponding states: Consider a gas of particles in a volume V interacting via a pair potential $U(r)$. Sketch a typical form of $U(r)$. Suppose that for a class of substances, $U(r)$ has the form $U(r) = \epsilon\, u(\frac{r}{\sigma})$. The meaning is that the energy scale is set by ε, the length scale is set by σ. Working in the canonical ensemble, show that all substances in this class have the same equation of state, when expressed in suitably scaled dimensionless variables: $p^* = \Pi(v^*, T^*)$. Here starred quantities are scaled pressure, volume per particle and temperature.