PHYS1231 end of year test 2001

The following equations may be used with proof.

$PV = NkT = nRT$ $\quad P = \frac{1}{3}\rho\overline{v^2}$ $\quad I = e\sigma T^4$

$x' = \gamma(x - vt)$ $\quad t' = \gamma(t - vx/c^2)$ $\quad u'_x = \dfrac{u_x - v}{1 - u_x v/c^2}$ $\quad \gamma = \dfrac{1}{\sqrt{1 - v^2/c^2}}$ $\quad E^2 = p^2c^2 + m^2c^4$

$\lambda_{max}T = 2898\ \mu m.K$ $\quad \lambda - \lambda' = \dfrac{h}{m_e c}(1 - \cos\theta)$ $\quad E_n = -\dfrac{13.6\ eV}{n^2}$ $\quad p = h/\lambda$

$m_e = 9.1\ 10^{-31}$ kg $\quad e = 1.6\ 10^{-19}$ C $\quad h = 6.63\ 10^{-34}$ Js $\quad k = 1.38\ 10^{-23}\ JK^{-1}$.

$\sigma = 5.67\ 10^{-8}\ Wm^{-2}K^{-4}$

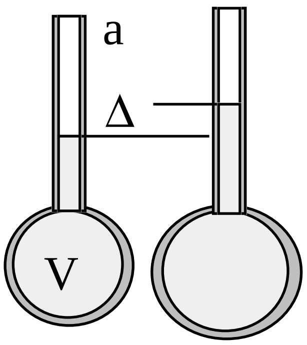
$\mathbf{F}_e = -\dfrac{1}{4\pi\varepsilon_o}\dfrac{q_1q_2}{r^2}\hat{\mathbf{r}}$

Question 1 (22 marks)

a) Using the equation of state for an ideal gas, derive an expression for the density ρ of an ideal gas in terms of the pressure P, temperature T, molecular mass m and constants.

b) Derive an expression for the volumetric coefficient of thermal expansion β for an ideal gas at constant pressure P. Give your answer in terms of the temperature T.

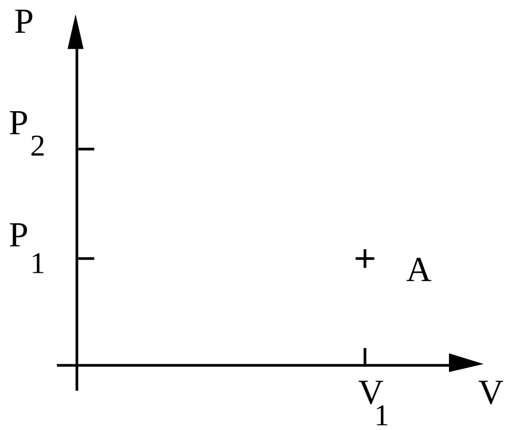
c)



The diagram shows a fluid-in-glass thermometer at two different temperatures: T and T + ΔT. The fluid has a coefficient of thermal expansion β_f and the glass has a coefficient of thermal expansion β_g, which is less than β_f, but which is not zero. The volume of the cylindrical part is very much smaller than that of the spherical part. When the temperature rises by ΔT, the liquid rises Δx in the cylindrical part of the thermometer, as shown.

Derive an expression for the ratio $\Delta x/\Delta T$ in terms of the given coefficients, the volume V of the fluid in the thermometer and a, the cross sectional area of the cylindrical section.

d)



Initially, n moles of an ideal gas are initally at volume V_1 and pressure P_1 (state A in the diagram).

A-B) The gas is then compressed *isothermally* to volume V_2 and pressure P_2 (state B).

B-C) The gas then expands *adiabatically* to volume V_3 and pressure P_1 (state C). (Note: it returns to the initial pressure.)

C-A) The gas is then returned *isobarically* (ie at constant pressure) to its inital state A.

i) Draw a sketch of this cycle on the P-V diagram.

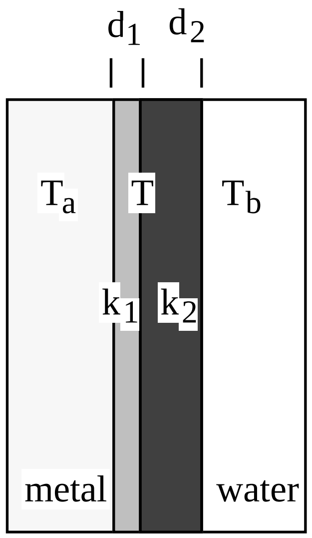
ii) State whether the isobaric process is an expansion or a contraction. Briefly (about two sentences), explain your answer.

iii) During which process or processes (A-B, B-C, C-A) is heat lost by the gas? Briefly (about two sentences), explain your answer.

iv) During which process or processes (A-B, B-C, C-A) is work done by the gas? Briefly (about two sentences), explain your answer.

Question 2 (16 marks)

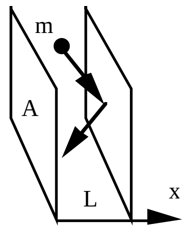
a)



A large, metal object is maintained at constant, uniform temperature T_a. It is coated with two uniform, thin layers of insulating material. The first coat has thickness d_1 and thermal conductivity k_1. The second coat has thickness d_2 and thermal conductivity k_2. The coated metal object is immersed in water at constant, uniform temperature T_b. A section of the object and coatings is shown in the sketch.

By considering the flow of heat through the coating, determine the temperature T at the interface between the two coatings, in steady state.

b)



N molecules of an ideal gas, each with mass m, are confined in a volume bounded by two parallel sides, each of area A, separated by a distance L in the x direction, as shown. Their motion is random and isotropic.

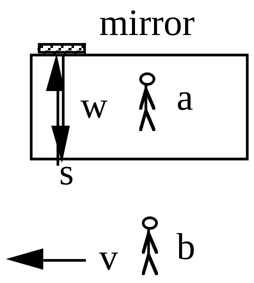
Apply Newton's laws to the collisions of the molecules with the walls, and thus relate the pressure acting on one of the square sides to N, m, the volume V and the mean value of the square of the x components of molecular velocity v_x.

Question 3 (14 marks)

a) State the principle of Gallilean or Netwonian relativity

b) State Einstein's principle of Special Relativity.

c)



An observer a sees a beam of light travel from source s to a mirror and return to the source, as shown. The mirror and the source are at rest with respect to observer a, and are separated by a distance w.

i) State the time t_a light takes to travel from source to mirror and back again, as measured by observer a.

Observer a observes that observer b is travelling at speed v to the left, and at right angles to the path of the light, as shown. Both observers agree that the distance between the source and the mirror, in the frame of a, is w, and that the magnitude of their relative speed is v.

ii) Draw a sketch of the path of the light ray, as observed by b. Using this sketch, determine the time t_b that light takes to travel from source to mirror and back again, as measured by observer b.

iii) Write an equation for t_a/t_b, as determined by observer b.

iv) What observation can b make about the rate of physical processes in a's frame of reference?

v) What observation can a make about the rate of physical processes in b's frame of reference?

Question 4 (12 marks)

a) State de Broglie's wave hypothesis for the electron, and explain how it applies to the Bohr model of the hydrogen atom. (A few sentences, and perhaps a diagram)

b) Explain briefly why the absorption spectrum of hydrogen consists of discrete lines, rather than a continuum.

c) Choose a physical phenomenon which may be explained by the Heisenberg Uncertainty Principle, and then briefly (about two sentences, perhaps including an equation) explain it.

Question 5 (16 marks)

i) Sketch the principal elements of an experiment involving light that demonstrates an effect associated with ***waves***. Name the effect, and explain very briefly what happens and why this demonstrates wave-like properties. (Your explanation could be several sentences, ***or*** it could be in point form. In either case, a diagram may be useful.)

ii) Sketch, or give a brief description of an experiment involving light that demonstrates an effect associated with ***particles***. Name the effect, and explain very briefly what happens and why this demonstrates properties normally associated with particles. (Your explanation could be several sentences, ***or*** it could be in point form. In either case, a diagram may be useful.)

iii) de Broglie proposed that electrons could have a wavelength. Explain briefly the phenomenon that he explained using this wavelength. (Your explanation could be several sentences, ***or*** it could be in point form. In either case, a diagram may be useful.)