UNIVERSITÄT LEIPZIG

Experimental Physics IV IPSP

Problem Set 1

Deadline: Thursday, 14.04.2011, before the lecture

Problem 1: 4 points

In the 19th Century nuclear fission and fusion were unknown. Therefore, it was assumed that the sun could at best be made out of coal. However, it turned out that the calculated burn duration is much too small to support this idea when comparing to the geological age of the earth.

Calculate the burn duration of a hypothetical "sun made out of coal" (Neglect the needed volume/mass of oxygen)!

Luminosity of the sun:	$L_S = 3.846 \cdot 10^{26}\ \mathrm{W}$
Diameter of the sun:	$d_S = 1.391 \cdot 10^6\ \mathrm{km}$
Density of coal:	$\rho_C \approx 2.3\ \frac{\mathrm{g}}{\mathrm{cm}^3}$
Heat of combustion of coal:	$H_C = 32.8\ \frac{\mathrm{MJ}}{\mathrm{kg}}$

Problem 2: 2+3+2+4 points

A flask is filled with 2,24 dm^3 oxygen under standard condition for temperature and pressure (STP, 0°C, $101.325\ \mathrm{kPa}$).

a) How many oxygen molecules are in the flask? (Hint: molar volume of gases)
b) Calculate the mean free distance of two neighboring oxygen molecules! (Hint: Assume a simple cubic lattice for the position of the oxygen molecules)
c) The effective molecular radius of O_2 is $73\mathrm{pm}$. Calculate the atomic packing factor (ratio of the volume occupied by atoms per unit cell) given by $F = \frac{N_{\mathrm{oxygen}} V_{\mathrm{oxygen}}}{V_{\mathrm{unit\ cell}}}$ with the volume of a unit cell $V_{\mathrm{unit\ cell}}$, the number of oxygen molecules in the unit cell N_{oxygen} and the volume of oxygen molecule V_{oxygen} !
d) Sodium chloride builds a simple cubic lattice with alternating Na and Cl atoms. Draw a sketch of the unit cell, calculate the atomic packing factor of a $NaCl$ crystal and compare it with the atomic packing factor in c)!

effective radius of Na^+:	$r_{Na} = 95\mathrm{pm}$
effective radius of Cl^-:	$r_{Cl} = 181\mathrm{pm}$
distance $Na - Cl$:	$d_{Na-Cl} = 282\mathrm{pm}$

Problem 3: 3+2+2 points

For the slit experiment the intensity minima and maxima can be calculated with basic trigonometry. However, basic trigonometry does not provide the shape of the intensity diffraction pattern. The qualitative shape can be achieved i.e. by Fourier-transformation of the signal function.

Calculate the intensity diffraction pattern of a single slit by using Fourier-transformation!

a) Calculate $\hat{S}(k_x)$ by Fourier-transforming! (Definition is given below)
b) Express k_x as a function of α! Substitute $k_x(\alpha)$ in $\hat{S}(k_x)$ to obtain $\hat{S}(\alpha)$!
c) Calculate $\hat{S}(\alpha = 0)$! Finally calculate the normalized intensity diffraction pattern defined by

$$\frac{I(\alpha)}{I(0)} = \left|\frac{\hat{S}(\alpha)}{\hat{S}(0)}\right|^2$$

Signal function for a single slit:

$$S(x) = \begin{cases} 0 & \text{for} \quad x < -\frac{d}{2} \\ 1 & \text{for} \quad -\frac{d}{2} \leq x \leq +\frac{d}{2} \\ 0 & \text{for} \quad x > \frac{d}{2} \end{cases}$$

Definition of the continuously Fourier-transformation:

$$\mathcal{F}(S(x))(k_x) = \hat{S}(k_x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} S(x) e^{-ik_x x} \mathrm{d}x$$