Problem set in Optical Spectroscopy in Materials Science

2018/2019 Spring

1) A glass rod with thickness t is placed in a homogenous magnetic field **B**, which is parallel to the rod. When a light beam propagates in the glass along the field its polarization is rotated (Faraday-effect). Derive the magnitude of the polarization rotation as a function of field and thickness, if the refractive index difference for the two circularly polarized states is equal to $\Delta n_{\pm}=V*B$, where V is a material specific constant. What happens if the light beam propagates through a sugar solution?

2) Derive the reflectivity of a bulk metal in the low- and high-frequency limits. (The low frequency limit is referred as the Hagen-Ruben law.)

3) Calculate the joint density of states for electrons with linear energy-momentum dispersion (Dirac particles) in 1, 2 and 3 dimensions. Why the optical conductivity of graphene is frequency independent? (Experimental data: Nature Physics 4, 532 (2008))

4) Estimate the plasma frequency in alkali metals (Li, Na, etc) and in strongly doped semiconductors (GaAs, InSb, etc.). Compare your results with the measured values, and interpret your findings.

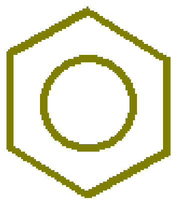
5) Calculate the absorption strength of the 1S - 2P transition in atomic hydrogen gas, which is in normal state. Assume that the lifetime broadening is $\gamma=6\times10^{8}$ 1/s.

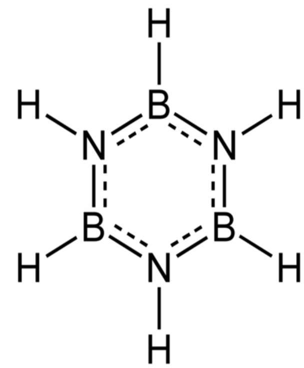
6) Derive the Fresnel equations for *s*- and *p*-polarized incident light, respectively, at the interface of two media (Lecture 7, slides 7-8). Calculate the Brewster angle ($r_p=0$) for external reflection ($n_a/n_b < 1$) and the critical angle (total reflection) for internal reflection ($n_a/n_b > 1$). In all cases, assume that the index of refraction is real.

7) Derive the formula of the complex dielectric function from the Fresnel equations using the ellipsometric angles and the infinite, isotropic two-phase model (Lecture 7, slides 7-8 and 12). When modeling the measurement, assume that the incidence medium is air.

8) We have heard in the lecture of Zoltán Németh that in Mössbauer spectroscopy, energy is measured in units of mm/s. Describe how the measurement is performed and how these units can be converted to energy. (short ppt presentation will be provided).

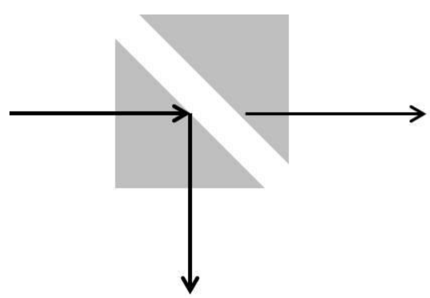
9) Determine the expected number and symmetry of the IR and Raman-active modes of the molecules of benzene and borazine, respectively. How does the frequency of the B-H and N-H vibrations of borazine change provided the bond strength is constant?





10) The experimental arrangement shown below is used for detecting the evanescent field. By changing the distance between the two prisms, the intensity of light behind the second prism is changing. Assuming the index of refraction of the prism to be n=1.5, and the wavelength of incident light to be 500 nm, calculate

a) at what distance does the light intensity reduce to 1/e of the incident one;
b) in the case of 1 mm distance, what is the intensity entering the second prism?



11) Derive the Raman depolarization ratio for randomly oriented particles.