PHYS 446 Fall 2015

Homework Assignment 4 Due Nov 2

1. NaCl has a high-frequency value of the optical index of refraction 1.5 and longitudinal and transverse optical phonon frequencies $\omega_L = 5.0\times10^{13}$ rad/s, $\omega_T = 3.08\times10^{13}$ rad/s. Calculate the static dielectric constant $\varepsilon_r(0)$ and the percentage contribution of the ionic polarizability.

2. Calculate the plasma frequency for n-type GaAs (at room temperature) for the concentration of shallow donors 5×10^{17} cm^{-3}. Electronic effective mass is $m_e = 0.063m_0$. Relative dielectric constant of GaAs in the visible spectral range is 9, while the very low (radio-) frequency dielectric constant is close to 12. At what donor concentration the plasma frequency is equal to that of the longitudinal optical phonon (which energy is 36 meV)? (When the carrier concentration is close to this value, so-called mixed plasmon-phonon modes are observed).

3. From the data table on the back side (first two columns – real and imaginary parts of the dielectric function) determine the optical reflectivity (at normal incidence) of silicon at $\lambda = 496$ nm. What fraction of total incident intensity will penetrate through the 100-nm thick Si film?

4. Derive the temperature dependence of the Stokes-to-AntiStokes intensity ratio $\frac{I_{St}(\hbar\Omega_{ph},T)}{I_{aSt}(\hbar\Omega_{ph},T)}$ using the Planck distribution function. Plot the Stokes-to-AntiStokes intensity ratio $\frac{I_{St}(\hbar\Omega_{ph},T)}{I_{aSt}(\hbar\Omega_{ph},T)}$ for the phonon frequency $\hbar\Omega_{ph}$ of 100 cm^{-1}. You may find it useful to convert phonon energy to the units of kT to simplify calculations.

D. E. Aspnes, A. A. Studna, Phys. Rev. B **27**, 985 (1983)

TABLE II. Optical properties of Si.

E (eV)	$\langle\epsilon_1\rangle$	$\langle\epsilon_2\rangle$	n	k	R	$10^3\alpha$ (cm^{-1})
1.500	13.488	0.038	3.673	0.005	0.327	0.78
1.600	13.793	0.057	3.714	0.008	0.331	1.25
1.700	14.079	0.078	3.752	0.010	0.335	1.80
1.800	14.413	0.099	3.796	0.013	0.340	2.38
1.900	14.797	0.126	3.847	0.016	0.345	3.15
2.000	15.254	0.172	3.906	0.022	0.351	4.47
2.100	15.754	0.236	3.969	0.030	0.357	6.32
2.200	16.334	0.260	4.042	0.032	0.364	7.17
2.300	16.994	0.396	4.123	0.048	0.372	11.19
2.400	17.761	0.508	4.215	0.060	0.380	14.65
2.500	18.661	0.630	4.320	0.073	0.390	18.48
2.600	19.724	0.803	4.442	0.090	0.400	23.81
2.700	20.987	1.193	4.583	0.130	0.412	35.63
2.800	22.565	1.548	4.753	0.163	0.426	46.22
2.900	24.574	2.017	4.961	0.203	0.442	59.75
3.000	27.197	2.807	5.222	0.269	0.461	81.73
3.100	30.874	4.321	5.570	0.387	0.486	121.62
3.200	36.355	7.636	6.062	0.630	0.518	204.28
3.300	43.264	17.717	6.709	1.320	0.561	441.68
3.400	35.224	35.282	6.522	2.705	0.592	932.13
3.500	22.394	33.818	5.610	3.014	0.575	1069.19
3.600	19.124	31.632	5.296	2.987	0.564	1089.90
3.700	17.231	31.527	5.156	3.058	0.563	1146.67
3.800	15.531	32.229	5.065	3.182	0.568	1225.46
3.900	13.965	33.567	5.016	3.346	0.577	1322.69
4.000	12.240	35.939	5.010	3.586	0.591	1454.11
4.100	9.364	39.947	5.020	3.979	0.614	1653.60
4.200	2.371	45.348	4.888	4.639	0.652	1974.84
4.300	−12.404	44.095	4.087	5.395	0.703	2351.38
4.400	−18.818	33.350	3.120	5.344	0.726	2383.23
4.500	−19.815	24.919	2.452	5.082	0.740	2317.99
4.600	−17.931	18.601	1.988	4.678	0.742	2181.15
4.700	−15.190	15.094	1.764	4.278	0.728	2038.07
4.800	−13.087	13.193	1.658	3.979	0.710	1936.06
4.900	−11.507	11.974	1.597	3.749	0.693	1862.11
5.000	−10.242	11.195	1.570	3.565	0.675	1806.67
5.100	−9.291	10.776	1.571	3.429	0.658	1772.70
5.200	−8.724	10.655	1.589	3.354	0.646	1767.66
5.300	−8.751	10.586	1.579	3.353	0.647	1801.26
5.400	−9.168	9.907	1.471	3.366	0.663	1842.63
5.500	−9.106	8.846	1.340	3.302	0.673	1840.59
5.600	−8.726	7.999	1.247	3.206	0.675	1820.07
5.700	−8.325	7.400	1.186	3.120	0.673	1802.31
5.800	−7.987	6.898	1.133	3.045	0.672	1789.99
5.900	−7.721	6.460	1.083	2.982	0.673	1783.51
6.000	−7.443	5.877	1.010	2.909	0.677	1769.27