PHY475: Numerical answers to past exam papers

Autumn Semester 2016-17

Question	Answer
1	(c) (i) ~ 1.7 (c)(ii) ~200 m^{-1} (c)(iii) $\omega_0 \sim 3.4 \times 10^{15}$ rad/s; $\gamma \sim 3 \times 10^{14}$ s^{-1}; $\alpha \sim 1 \times 10^5$ m^{-1} (c) (iv) oscillator strength $f \sim 10^{-3}$
2	(c) 818.4 nm; 816.8 nm (e) 788 nm and 769 nm, assuming exciton binding energy ~ 0.01 eV
3	(b)(i) 0.086 eV (electrons) and 0.012 eV (holes) (b)(ii) 1.519 eV to 1.617 eV, following density of states (b)(iii) 3.9×10^8 m^{-1} and 2.9×10^7 m^{-1} (c) Narrowing due to lasing
4	(e) 99.6%
5	(b) 13 GHz (c)(i) Stokes and anti-Stokes peaks; 517 cm^{-1} (c)(ii) Anti-Stokes freezes out (c)(iii) LO and TO modes are degenerate in silicon. Not so for polar crystals like III-Vs (c)(iv) No Reststrahlen band for silicon. (d) 5 ps. Anharmonic decay to two acoustic phonons. Will broaden with T as the number of acoustic phonons increases.

Autumn Semester 2015-16

Question	Answer
1	(b) (i) ~ 5.8 (b) (ii) ~ 5×10^{12} Hz (b) (iii) ~ 7×10^{12} s^{-1} (b) (iv) ~ 8×10^{5} m^{-1}
2	(b) E_g^{ind} ~ 2.2 eV; E_g^{dir} ~ 2.8 eV. Would work OK as a solar cell, but not as efficiently as Si: solar spectrum peaks in green, and no photons below 2.2 eV absorbed. (c) 0.24 A/W (d) Peaks at 7.4 μm and 1.5 μm (1→2 and 1→4 transitions respectively). Broadened by well width fluctuations, etc. (e) Transitions shift to longer wavelength. Maybe n=4 state not bound, so 1→4 transition might disappear.
3	(c)(i) See Fig. 5.6; (ii) should be flat from (E_g + E_{e1}+E_{hh1}) up to Fermi energies due to 2-D DOS; (iii) Sharp peak at QD transition energy; (iv) inhomogeneously broadened peak due to variation in dot sizes (d) 14nm, assuming infinite well model. Would need to be smaller in reality due to finite well depth. (e) Red shift and reduction of intensity due to quantum confined Stark effect.
4	(a) Atoms uncharged, so no phonon absorption, as no dipole interaction with electric field of light. (c) ~30% reflectivity at 10μm; drops to zero just below wavelength of plasma frequency (37μm); 100% reflectivity from 37→100 μm (d) 9×10^{3} m^{-1}
5	(c) $\chi^{(2)}$ = 0 if the material has inversion symmetry. (e) 0.34π

Autumn Semester 2014-15

Question	Answer
1	(b) ice, strained glass, graphene (c) 14 μm (d) Good for both. Both need lack of inversion symmetry. (e)(ii) 1.8×10^{7} V m^{-1}
2	(b) ~9 nm (c) smaller. Infinite well model overestimates confinement energy. (d) Read from graph. About 11 - 12 meV. Would be 16.8 meV (4 times bulk) in ideal 2D material. QW in only approximately 2D. (e) Examples: single QW, single QD layer, 2D monolayer, absorber on opaque substrate
3	(d)(i) electrons 185 meV, holes 0.011 meV (d)(ii) electrons significant because $E_F > k_B T$ (e) 379 nm. Infinite well model overestimates confinement energy. In-built field gives quantum confined Stark effect large. Exciton binding increases wavelength.
4	(a) γ determined by fitting reflectivity or measuring conductivity (c) damping + interband transitions (d)(i) 8.6×10^{27} m^{-3} (ii) Effective mass larger than m_e (f) (i) Electron energy loss spectroscopy (ii) Raman spectroscopy (g) Bulk and surface plasmons. Surface plasma frequency factor of $\sqrt{2}$ larger
5	(a)(iii) Need also to consider low frequency tail of electronic absorption (b)(i) 35% (b) (ii) 45.5 μm and 41.3 μm (b) (iii) 41.0 μm (b) (iv) 93% (b)(v) Anharmonic decay of TO phonon to two acoustic phonons (Klemens channel)