PHY475: Numerical answers to past exam papers

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)

Autumn Semester 2013-14

Question	**Answer**
1	(b) Dopants create extra absorption in UV below band gap. Reduces omega_0, and hence changes dispersion (c) 0.94 (d) Group velocity dispersion zero at inflection points. (e) ~0.6
2	(c)(i) Long wavelength cut off at band gap. Linear part: see eqn 3.39 with αl large. Drop in efficiency below 500nm due to strong absorption in top contact. (c)(ii) 85% and 53%. Optimize coating for short wavelengths. Use thin top contact. (c)(iii) Band gap increases, so long wavelength cut off reduces. Benefit: lower dark current. (c)(iv) Want large gap for high open circuit voltage, and small gap for high short circuit current. Hence compromise on efficiency in single-junction solar cell.
3	(b) 76% and 7.5%. Drop at 300 K due to activation of non-radiative decay channels, eg traps, mutli-phonon emission, etc (d)(i) 871 nm, (ii) 834 nm, (iii) 739 nm (e)(i) 50% (e)(ii) Drops as slit off hole transitions excited.
4	(b)(ii) Smaller, 1.6×10^{24} m^{-3}, (iii) 0.062 m_e, (iv) 2.5×10^{4} m^{-1}
5	(b) Stokes possible at all temperatures, but anti-Stokes frozen out at low temperatures. Linewidth increases with T due to enhanced decay of optical phonons to two acoustic phonons stimulated by the increased number of phonons. (c) Two Raman lines in polar semiconductors due to LO and TO phonons with different frequencies. LO and TO phonons of non-polar semiconductors are degenerate. (d) Much smaller shifts, so harder to observe signal on top of background of elastically scattered laser photons. Determine speed of sound for high frequency acoustic phonons. (e) 1.25