1.4:

At 300 K, $E_g(GaAs) = 1.424$ eV and $E_g(Al_{0.2}Ga_{0.8}As) = 1.673$ eV (from Table 1.1).

Assume that the conduction band offset is roughly 2/3 of the energy gap difference (see p.10): $V_0 = 166$ meV.

Approximate the electron effective mass as the effective mass of the electrons in GaAs ($= 0.067m_0$ by Table 1.1).

From Appendix 1:

$$E_1^{\infty} = 2.76\left(\frac{1}{0.067}\right)\left(\frac{100\mathring{A}}{100\mathring{A}}\right) = 56.1 \text{ meV} \qquad (A1.14)$$

By Eq. A1.17

$$\begin{aligned} n_{max} &= \sqrt{\frac{V_0}{E_1}} \\ &= \sqrt{\frac{166 \text{ meV}}{56.1 \text{ meV}}} \\ &= 1.72 \end{aligned}$$

---

a) There are two bound states since $1 \leq n_{max} < 2$.

---

b) Using Figure A1.4, find the quantum numbers:

$$\begin{aligned} n_{QW_1} &= 0.724 \\ n_{QW_2} &= 1.397 \end{aligned}$$

$$\begin{aligned} E_n &= n_{QW}^2 \, E_1 \\ E_1 &= 29.4 \text{ meV} \\ E_2 &= 109 \text{ meV} \end{aligned}$$

1.6:

a)

$$E = E_1 + 2\Delta E \cos(ka) \tag{A1.27}$$

$$\Delta E = 0.2 \text{ eV}$$

$$a = 0.3 \text{ nm}$$

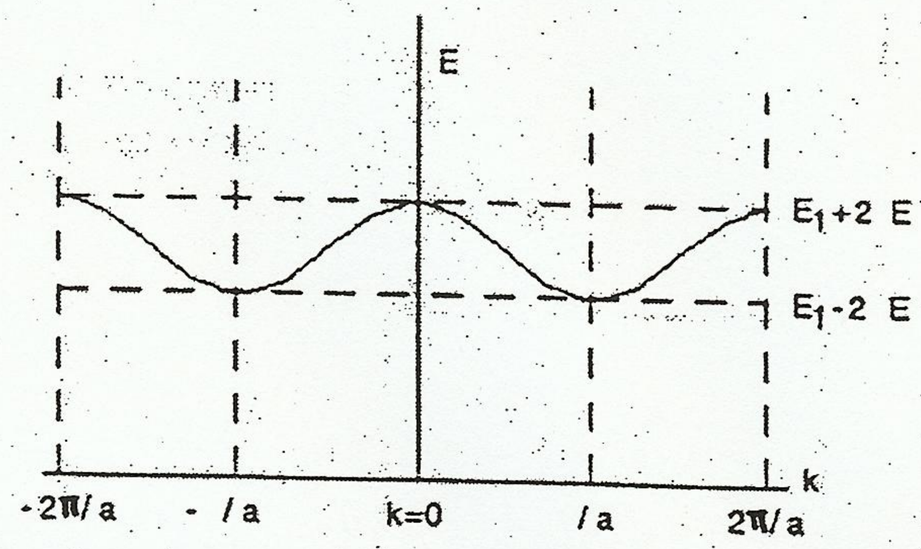

Figure 1.6a. Energy band over the first two Brillouin zones ($\frac{-2\pi}{a} \leq k \leq \frac{+2\pi}{a}$)

b)

$$m^* = \hbar^2 \left(\frac{\delta^2 E}{\delta k^2} \right)^{-1}$$

$$= \hbar \left(\frac{\delta}{\delta k} \frac{\delta}{\delta k} (E_1 + 2\Delta E \cos(ka)) \right)^{-1}$$

$$= \frac{-\hbar^2}{2\Delta E a^2 \cos(ka)}$$

For a minimum of the energy band, $\cos(ka) = -1 \quad m^* > 0$.

For a maximum of the energy band, $\cos(ka) = +1 \quad m^* < 0$.

$$\frac{m^*}{m_0} = \pm \frac{\hbar^2}{2\Delta E a^2 m_0}$$

$$= \pm \frac{(6.59 \times 10^{-16} \text{ eV s})^2 \ (3 \times 10^{10} \frac{\text{cm}}{\text{s}})^2}{2(0.2 \text{ eV})(0.3 \times 10^{-7} \text{ cm})^2 \ (0.511 \times 10^6 \text{ eV})}$$

$$= \pm 2.12$$

where we have used $m_0 = 0.511 \text{ meV}/c^2$.

1.7:

$$E_g(GaAs) \approx 1.42 \text{ eV}$$

$$\lambda_g = \frac{1.24 \text{ eV}\mu\text{m}}{E_g}$$

$$= 873 \text{ nm}$$

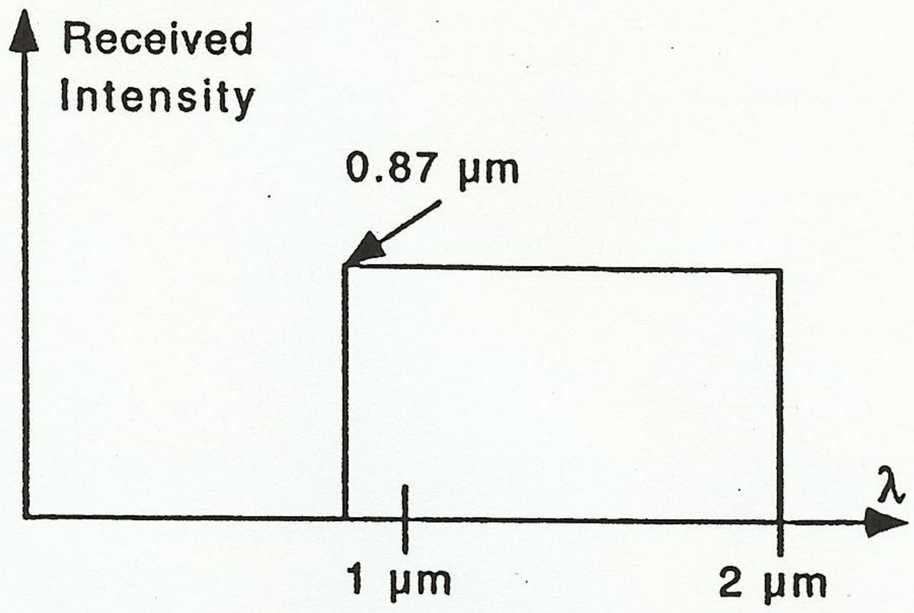

Figure 1.7. Recieved intensity vs. wavelength

Absorption: (R_{21})

All photons with energies greater than the bandgap (i.e. wavelengths < 873 nm) will be absorbed (This assumes reasonably low powers and that the wafer is more than a few microns thick.) This process will generate electron-hole pairs in the sample.

Non-radiative Recombination: (R_{nr})

The electron-hole pairs must recombine and one way is non-radiatively. The e-h pair will recombine and dissipate energy as lattice vibration (heat).

Spontaneous and Stimulated Emission: (R_{sp} and R_{st})

Some e-h pairs will recombine and create a photon. Photons generated by both processes will be near the bandgap energy (with a thermal distribution). Measuring the peak wavelength of the light emitted from a semiconductor when it is illuminated by an above bandgap source is a good way to determine the bandgap of an unknown material.

1.8:

a) The semiconductor is being "bleached" by the Argon pump. The Argon laser light is being absorbed and this is generating e-h pairs. If the e-h pairs are being generated at a fast enough rate, the number of available states in the conduction band and valence band is being reduced so there aren't enough to completely absorb the GaAs laser light.

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b) If the power is doubled to 6 W, the rate which e-h hole pairs are generated is not doubled: If the GaAs power is only 50% absorbed, additional power from the Argon laser will be less than fully absorbed. So 6 W will not double the e-h generation rate. Also, the recombination rate increases if more e-h pairs are present because $R_{sp} \propto np$. So to completely bleach the material, more power is needed to overcome both the decreased absorption and the increased recombination rate.