Solution sheet - Tute-9, Laser Technology.

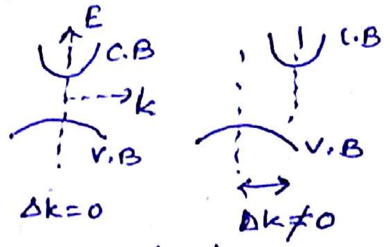
Q1. $\lambda = 10.6\,\mu m = \frac{hc}{E} \Rightarrow E = 1.875\times10^{-20}\,J \Rightarrow t = \frac{E}{P} = 1.875\times10^{-23}\,s$

So number of Photons emitted in 1 minute $= \frac{60}{1.875\times10^{-23}} = 3.2\times10^{23}$

Q2. Input power $= 2\times230\,W = 460\,W$, output power $= 10\times10^{-3}\,W$ $\Big\}$ Efficiency $= \frac{\text{Output}}{\text{Input}}\times100 = \cancel{21\%}$ $= 21.74\,\%$

Q3. $\Delta k = 0$ for direct band gap $\longrightarrow$ GaAs, AlGaAs, GaN
$\Delta k \neq 0$ for indirect " material $\rightarrow$ Si, Ge

For Light emitting diode material $\rightarrow$ Direct band gap material.
as $\Delta k = 0$ (no loss of energy during recombination of e' and holes.



Q4. $R = \left|\frac{n_1-n_2}{n_1+n_2}\right|^2 = \left|\frac{3.6-1}{3.6+1}\right|^2 = \left|\frac{2.6}{4.6}\right|^2 = 0.319$ or $31.9\,\%$

Q5. $\frac{\Delta n e}{\tau} = \frac{2.02\times10^{18}\,cm^{-3}\times1.6\times10^{-19}\,C}{4\times10^{-9}} = 8.08\times10^{+8}\,\frac{A}{cm^3}$, $J_{th} = \frac{\Delta n e d}{\tau}$

(a) If $d = 0.1\,mm = 10^{-2}\,cm \Rightarrow J_{th} = 8.08\times10^{8}\times10^{-2}\,A/cm^2 = 8.08\times10^{6}\,A/cm^2$

(b) If $d = 0.1\,\mu m = 10^{-5}\,cm \Rightarrow J_{th} = 8.08\times10^{3}\,A/cm^2$

(c) If $d = 10\,nm = 10^{-6}\,cm \Rightarrow J_{th} = 8.08\times10^{2}\,A/cm^2$

Q6. $E_g = \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\times3\times10^{8}}{1.55\times10^{-6}\times1.6\times10^{-19}}\,eV = 0.8\,eV$

Note $\rightarrow$ $\boxed{E_g(eV) = \frac{1.242}{\lambda(\mu m)}}$

Q7. (i) $x = 0.1 \Rightarrow E_g = 1.424 + 1.266\times0.1 = 1.55\,eV \Rightarrow \lambda = 8013\,\mathring{A}$

(ii) $x = 0.2 \Rightarrow E_g = 1.424 + 1.266\times0.2 = 1.677\,eV \Rightarrow \lambda = 7406\,\mathring{A}$

For AlAs $\Rightarrow x = 1 \Rightarrow E_g = 2.69\,eV \Rightarrow \lambda = 4617\,\mathring{A}$

For GaAs $\Rightarrow x = 0 \Rightarrow E_g = 1.424\,eV \Rightarrow \lambda = 8722\,\mathring{A}$

Q8. $(E_g)_{Eff} = (E_g)_{Bulk} + \frac{h^2}{8m_cL^2} + \frac{h^2}{8m_vL^2} \Rightarrow (E_g)_{Bulk} + \left(\frac{1}{m_c}+\frac{1}{m_v}\right)\frac{h^2}{8L^2}$

here $\left(\frac{1}{m_c}+\frac{1}{m_v}\right)\frac{h^2}{8} = 6.445\times10^{-18}\,eV\text{-}m^2$, $(E_g)_{Bulk} = 1.424\,eV$

Case II $L = 10\,nm \Rightarrow (E_g)_{eff} = 1.424\,eV + \frac{6.445\times10^{-18}}{10^{-16}}\,eV = 1.424 + 0.06445 = 1.48845\,eV$

and $\boxed{\lambda = 8344\,\mathring{A}}$

Case-I $L = 1\,\mu m \Rightarrow (E_g)_{eff} \approx 1.424\,eV \Rightarrow \lambda = 8722\,\mathring{A}$

Case-III $L = 1\,nm \Rightarrow (E_g)_{eff} = 7.869\,eV \Rightarrow \lambda = 1578\,\mathring{A} \Rightarrow$ Quantum dot effect.