EE4441 Hour Exam 2, Spring 2015

Each problem is worth 6 points. All units are mks and are considered part of the answer. Show your work for full credit. Useful constants:
Boltzmann’s constant $= 1.38054 \times 10^{-23}$ J/K
Stefan-Boltzmann constant $= \sigma = 5.6697 \times 10^{-8}$ W/m$^2$-K$^4$
h = 6.6256 $\times 10^{-34}$ J-s = 4.135 $\times 10^{-15}$ eV-s
c = 3 $\times 10^8$ m/s

1. What is the power radiated (black-body) from a surface 1cm x 1cm at temperature T=5700K in the frequency range 590-610nm?

$$\text{Power} = \frac{2 \pi c^2 \hbar}{\lambda^5 \left( e^{\frac{h c}{\lambda \kappa T}} - 1 \right)}$$

$$= \frac{9.6 \times 10^7}{e^{\frac{h c}{\lambda \kappa T}} - 1}$$

$$= 1.42 \times 10^6 \text{ [W/m}^2\text{]}$$

2. A helium-neon laser with a gain length of L=0.25m is installed in a two-mirror cavity having mirror reflectivities of 99% and 98%. Assuming scattering losses of $a_1 = a_2 = 0.001$ and absorption loss $\alpha = 0.01$, find the threshold gain, $g_{th}$.

$$g_{th} = \frac{1}{2L} \ln \left[ \frac{R_1 R_2 (1-a_1)(1-a_2)}{1} \right] + \alpha$$

$$= 0.074$$
3. A laser has a length, $L$, of 0.1 m at $\lambda=632.8$nm, a single pass gain $I/I_0=10$, and scattering losses per pass of 0.5%. What is the optimum transmission for the output mirror, assuming the other mirror has $R=1$?

$$A_{opt} = (g_0 L \alpha)^{1/2} - \alpha \quad (\alpha = 0.005)$$

$$\frac{I}{I_0} = 10 = e^{g_0 L} \Rightarrow g_0 L = 2.3$$

$$A_{opt} = 0.102$$

4. The Nd:YAG laser is a four-level laser with $\gamma_{ul} = 4.3 \times 10^3 \text{s}^{-1}$, and energy separation $\Delta E_{lo} = 0.25 \text{eV}$. Find the threshold pumping flux, $\Gamma_{th}$, required at $T=300 \text{K}$.

$$\Gamma_{th} > e^{-\Delta E_{lo}/kT} \gamma_{ul}$$

$$= e^{-0.25/(8.6 \times 15^3 \times 300)} \approx 4.3 \times 10^3$$

$$= 0.266 \left[ \frac{1}{s} \right]$$
5. Estimate the power required to pump a laser rod to the threshold value if the rod is 5mm diameter, 10 cm long, the required pumping flux is \(5 \times 10^{27} [1/(m^3 \text{s})]\), the upper state lifetime is \(\tau_u = 1 \times 10^{-3} [1/\text{s}]\), and the laser wavelength is 555nm.

\[
\frac{\text{Photons}}{s} = (\text{pumping flux}) \times \text{Volume} \\
= 5 \times 10^{27} \left( \pi \right) \left(2.5 \times 10^{-3} \right)^2 \text{ cm}^3 \\
= 9.8 \times 10^{21} / s \\
\text{Power} = \left( \frac{\text{Photons}}{s} \right) \frac{h \epsilon}{\lambda} = 3.5 \text{ kW}
\]