Part I.

1. (25 pts) **Multi-beam interference in Fabry-Perot interferometer.** A useful device based on multi-beam interference is the Fabry-Perot interferometer (or etalon). It consists of two parallel mirrors within which light undergoes multiple reflections and transmissions. Prove that

(i) the phase difference between adjacent reflected or transmitted beams is (5 pts)

$$\delta=4\pi n_f d\cos\theta_t/\lambda_0 ,$$

where λ_0 is wavelength of incident beam in vacuum, n_f and d are the refractive index of the medium in the gap of the interferometer and the thickness of gap, respectively, and θ_t is the refractive angle of the incident beam entering into the gap.

(ii) the intensities of the superposition of the infinite number of reflected and transmitted waves of the interfaces of the interferometer are (20 pts)

$$I_r = I_i \frac{F\sin^2(\delta/2)}{1+F\sin^2(\delta/2)} \text{ and } I_t = I_i \frac{1}{1+F\sin^2(\delta/2)}, \text{ respectively,}$$

where $F=\left(\frac{2r}{1-r^2}\right)^2$, r is the amplitude - reflection coefficient of each coating film on the mirrors, and

δ is obtained from the answer in (a).

2. (15 pts) **Twisted nematic liquid crystal acting as a polarization rotator.** Consider the propagation of light along the axis of twist (the z axis) of a twisted nematic liquid crystal with a thickness of d and assume that the twist angle θ varies linearly with z (that is, $\theta = \alpha z$). The optic axis is therefore parallel to the x-y plane and makes an angle θ with the z direction. The principal ordinary and extraordinary refractive indexes are n_o and n_e, respectively (typically, $n_e > n_o$), and the phase-retardation coefficient (retardation per unit length) is $\beta = 2\pi(n_e-n_o)/\lambda_0$. Show that, if the incident wave (with wavelength λ_0 in vacuum) at $z = 0$ is linearly polarized in the x or y direction and if $\beta >> \alpha$, the twisted nematic liquid crystal can act as a polarization rotator (that is, the output wave can maintain its linearly polarized state but the plane of polarization rotates in alignment following with the molecular twist.

3. (10 pts) **Transmission of a Gaussian beam through a graded-index slab.** The ABCD matrix of a SELFOC graded-index slab with quadratic refractive index $n(y) \approx n_0(1-\frac{1}{2}\alpha^2 y^2)$ and length d is $A = \cos\alpha d$, $B = (1/\alpha)\sin\alpha d$, $C = -\alpha\sin\alpha d$, $D = \cos\alpha d$ for paraxial rays along the z direction. A Gaussian beam of wavelength λ_0 and waist radius W_0 in free space, and axis in the z direction enters the slab at its waist. Use the ABCD law to determine an expression for the beam width in the y direction as a function of d.

Part II

1. (5 pts) A resonator is constructed using concave mirror of radii 50 cm and 100 cm. Determine the maximum resonator length for which rays satisfy the confinement condition.

2. (5 pts) Write down the rate equation for a two level laser system and explain why a two level system is not feasible.

3. (25 pts) An optical-fiber Fabry–Perot cavity has a physical length of l=20 m, an intracavity refractive index of n =1.45, a distributed loss of α =0.005 m^{-1}, and mirror reflectivities of R_1=R_2=80%.
   (a) What are the round-trip time and the longitudinal mode frequency spacing of this cavity?
   (b) Find the finesse and the longitudinal mode width of this cavity.
   (c) What is the quality factor Q for λ=1.3 μm?

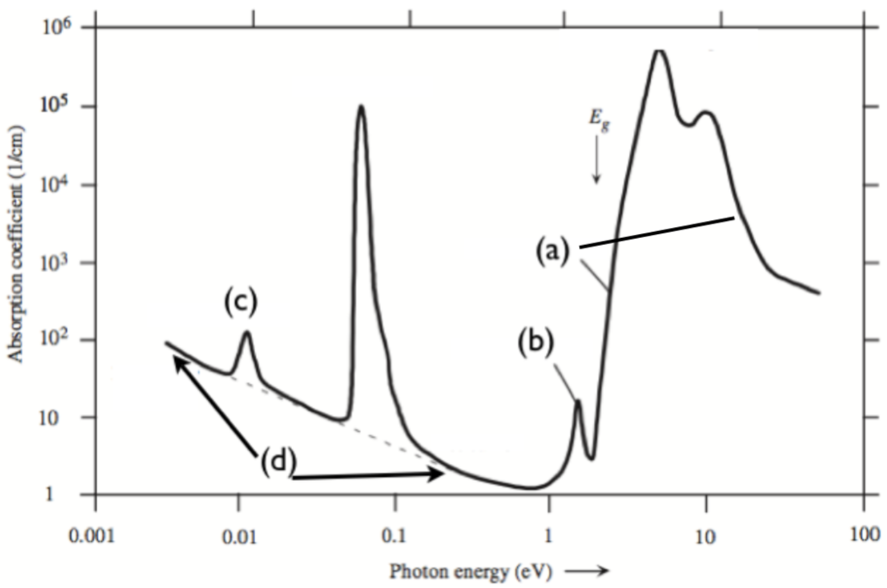
4. (10 pts) Explain the working principles of "Q-Switching" and "Mode Locking".

5. (5 pts) Explain the intensity modulation in a Mach-Zehnder interferometer with an electro-optic phase
   modulator.

Part III

1. (16 pts) Plot the energy band diagram, for (a) a homogeneous p-n junction and (b) a p-i-n junction at equilibrium at dark and forward bias.

2. (16 pts) Please describe the mechanism of the optical process (a, b, c, d) in the following absorption spectra for a semiconducting material.



3. (18 pts)

(a) What is a degenerate semiconductor ?

(b) What is a direct bandgap semiconductor ?

(c) What is a ohmic contact between a semiconductor and a metal ?

(d) What is the photoconductive gain for a semiconductor photodetector ?

(e) What is the external quantum efficiency or IPCE for a solar cell ?

(f) What is Cathodoluminescence ?