Name	
Surname	

OPTOELECTRONICS

Exam 1

Grade:

Problem 1	*Problem 2*
a)	a)
b)	b)
c)	c)
	d)

Questions		
1)	5)	9)
2)	6)	10)
3)	7)	11)
4)	8)	12)

Problem 1 (4 pts).

We have a SLED with an emitting square surface of 0.09 mm^2 That we want to inject into a 175/62.5 μmfiber with numerical aperture 0.2. The device allows a distance between the fiber and the surface of the SLED of 3.5 cm.

a) **Determine the type of lens required, the focal, and the position of the lens (2.5 pts)**
b) **Draw the system and do the ray tracing (1pts)**
c) **Determine the number of modes for a STEP and a GRIN fiber with the mentioned characteristics if the SLED emits at 1.05 μm (0.5pts)**

(TIP: The SLED is symmetrical, there is no problem if the image is flipped)

Problem 2. (7pts)

We have an p-n homojunction based on GaAs, that we want to use as a detector.

a) **Determine the intrinsic carrier density and the potential bias V_D using the provided values. (2pts)**
b) **Determine the external potential required so 95% of the light is absorb in the depletion region. (Neglect absorption in the p or n regions) (2pts)**
c) **Calculate the efficiency of this detector knowing that the maximum theoretical responsibility is 0.33. (1pts)**
d) **We have two possible light sources, GaAs and InP, calculate the most intense wavelength of emission for each one at room temperature. If the proportionality constant α_{emi} is equal for both semiconductors, discuss which one is going to create more current in the detector. (2pt)**

$T = 300\ K$	$m_e = 0.07 m_e^0$	$m_h = 0.56 m_e^0$
$\alpha = 0.7\ mm^{-1}$	$N_d = 5 * 10^{21}\ m^{-3}$	$N_a = 5 * 10^{23}\ m^{-3}$
	$\mu_e = 0.85\ m^2 \cdot V^{-1} \cdot s^{-1}$	$\mu_h = 0.04\ m^2 \cdot V^{-1} \cdot s^{-1}$
	$E_g(GaAs) = 1.43\ eV$	$E_g(InP) = 1.27\ eV$

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Questions. (0.75 pts each, 12 in total)

1. **After a given lens the beam rays converge. The image will be**
   a) Always virtual
   b) Always real
   c) Real only if the lens is convergent
   d) Real only if the object is virtual

2. **A planar monochromatic beam crosses the interface between two media with the same refractive index for that given wavelength $\boldsymbol{n_1 = n_2}$, but opposite dispersion regime (one is anomalous and the other is normal dispersion). The beam direction will remain constant, $\boldsymbol{\theta_1 = \theta_2}$,…**
   a) Only if the first medium has anomalous dispersion and the second normal dispersion
   b) Only if the first medium has normal dispersion and the second anomalous dispersion
   c) Always
   d) Never

3. **The reflected beam obtained at the Brewster angle will be:**
   a) Always linear polarized
   b) Always perpendicular to the plane of propagation
   c) Both a) and b)
   d) Neither a) nor b)

4. **Two given fields such as $\overrightarrow{\boldsymbol{E_1}}$ and $\overrightarrow{\boldsymbol{E_2}} = \overrightarrow{\boldsymbol{E_1}} \boldsymbol{e^{i\phi}}$ interfere at a given plane. This interference is:**
   a) Always constructive if $\phi = 0$ and destructive if $\phi = \pi$
   b) Always constructive if both waves are spherical
   c) Always destructive if both waves are planar
   d) It depends on the plane of observation

5. **Given injection only in the center of a generic circular GRIN fiber, which is the relation between the parameter $\boldsymbol{g}$ and the numerical aperture of that fiber.**
   a) The numerical aperture is linear with g, $NA \propto g$
   b) The numerical aperture is quadratic with g, $NA \propto g^2$
   c) The numerical aperture is inversely proportional to g, $NA \propto g^{-1}$
   d) The numerical aperture is independent of g

6. **Mark the true affirmation**
   a) Single mode optical fiber have always one mode independently of the signal wavelength

b) Optical fibers are very sensitive to external electric fields
c) Given a STEP and a GRIN fibers with the same parameters, the GRIN fiber will have less modes at any given wavelength
d) A drawback in optical fibers is their huge signal attenuation

7. The band-gap in an homojunction
a) Is determined by the dopant concentrations
b) Is greater in the depletion region
c) Is smaller in the depletion region
d) Is constant

8. The internal quantum efficiency
a) Is only determined by the lifetime of holes and electrons
b) Is only determined by the physical structure of the device
c) Is a combination of the internal and external efficiencies
d) This parameter does not exist

9. Mark the correct one.
a) Surface and edge emitting LEDs have always the same efficiency
b) Edge emitting LEDs have a linear response over a wide range.
c) Injection laser diodes produce mainly incoherent light
d) The difference between SLED, ELED and ILD is the wavelength emitted

10. In order to reduce the gain coefficient threshold, you can:
a) Increase the longitudinal length
b) Reduce the transmission in the edge faces
c) Either a) and/or b)
d) Neither a) nor b)

11. What is the main difference between photodiodes and photoconductors?
a) The photodiodes require an external potential but the photoconductors not
b) The photodiodes can detect high energy photons but the photoconductors not
c) The photodiodes involve at least two differently dopped semiconducntors but the photoconductors only one
d) The photodiodes are forward biased and photoconductors are reverse biased

12. Photodiodes are not sensitive to what kind of noise
a) Shot noise
b) Thermal noise
c) Dark noise
d) They are sensitive to all of them

Data.

$$e = -1.6 * 10^{-19}\ C$$

$$m_e^0 = 9.11 * 10^{-31}\ kg$$

$$\epsilon_0 = 8.854 * 10^{-12}\ \ F \cdot m^{-1}$$

$$\mu_0 = 1.257 * 10^{-6}\ N \cdot A^{-2}$$

$$h = 6.626 * 10^{-34}\ \ J \cdot s$$

$$c_0 = 3 * 10^8\ \ m \cdot s^{-1}$$

$$k = 1.381 * 10^{-23}\ J \cdot K^{-1}$$

$$N_A = 6.022 * 10^{23}$$

Equations.

Snell's Law

$$n_1 sin\theta_1 = n_2 sin\theta_2$$

Thin lens

$$\frac{1}{q} - \frac{1}{p} = \frac{1}{f}$$

Magnification

$$M = \frac{h'}{h} = \frac{n_1}{n_2}\frac{q}{p}$$

Brewster eq.

$$\theta_B = \arctan\frac{n_2}{n_1}$$

Fresnel coeffs.

$$r_\perp = \frac{n_1 cos\theta_1 - n_2 cos\theta_2}{n_1 cos\theta_1 + n_2 cos\theta_2} = \frac{\tan(\theta_1 - \theta_2)}{\tan(\theta_1 + \theta_2)}$$

$$t_\perp = \frac{2n_1 cos\theta_1}{n_1 cos\theta_1 + n_2 cos\theta_2}$$

$$r_{||} = \frac{n_2 cos\theta_1 - n_1 cos\theta_2}{n_1 cos\theta_2 + n_2 cos\theta_1} = -\frac{\sin(\theta_1 - \theta_2)}{\sin(\theta_1 + \theta_2)}$$

$$r_{||} = \frac{2n_1 cos\theta_1}{n_1 cos\theta_2 + n_2 cos\theta_1}$$

Current carrier densities

$$n_0 = N_c e^{-\frac{E_c - E_F}{kT}}$$

$$N_c = 2\left(2\pi m_e \frac{kT}{h^2}\right)^{3/2}$$

$$p_0 = N_v e^{\frac{E_v - E_F}{kT}}$$

$$N_v = 2\left(2\pi m_h \frac{kT}{h^2}\right)^{3/2}$$

$$n_{p0} = N_d e^{\frac{-eV_D}{kT}}$$

$$p_{n0} = N_a e^{\frac{-eV_D}{kT}}$$

Diffusion parameters

$$D_{h/e} = \frac{\mu_{h/e} kT}{e}$$

$$L_{h/e} = \sqrt{D_{h/e}\tau_{h/e}}$$

Power emission

$$P = \alpha_{emi}\left(E_{ph} - E_g\right)e^{-\frac{\left(E_{ph} - E_g\right)}{kT}}$$

Gain

$$G = R_1 R_2 e^{2\left(g - \alpha_{eff}\right)L}$$

ILD Efficiency

$$\eta = \eta_{int}\eta_{ext} = \eta_{int}\frac{\left(g_{th} - \alpha_{eff}\right)}{g_{th}}$$

Responsibility

$$\Re = \frac{I_p}{P_{in}} = \eta\frac{e}{h\nu} = \eta\frac{e}{hc}\lambda$$

Depletion region width

$$w = \sqrt{\frac{2\epsilon}{e}\left(V_d + V\right)\left(\frac{1}{N_a} + \frac{1}{N_d}\right)}$$