國立中山大學100學年度碩士班招生考試試題

科目：光電概論【材光系碩士班丙組】

Electrostatic Fields

1. A hollow spherical shell carries charge density $\rho = \frac{k}{r^2}$ in the region $a \le r \le b$, as shown in Fig. 1.

   On the other regions, the carries charge density is zero.

   (a) Find the electric field intensity E and the potential V in the region of $r > b$. (10%)

   (b) Find E and V in the region of $a < r < b$. (10%)

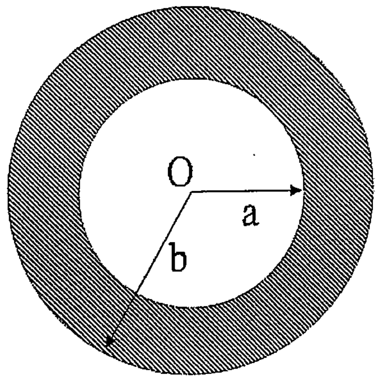

Fig. 1

2. The upper and lower conducting plates of a large parallel-plate capacitor are separated by a distance d and maintained at potentials V_o and 0, respectively (Fig. 2). Two dielectric slabs are placed between the two conducting plates. Dielectric slab A is placed over the lower plate with dielectric constant ε_{r1} and uniform thickness 0.8d. Dielectric slab B with a dielectric constant ε_{r2} is inserted between dielectric slab A and the upper plate. Assuming negligible fringing effect, determine

   (a) The potential and electric field distribution in the dielectric slab A. (10%)

   (b) The potential and electric field distribution in the dielectric slab B. (10%)

   (c) The surface charge densities on the upper and lower plates. (10%)

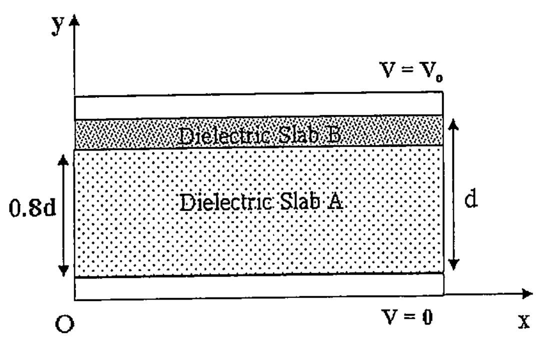

Fig. 2

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LED Operation

3. In semiconductors, the device containing a p-n junction for rectification is called a diode. When a diode is forward biased, a current flows through the device. The current consists of holes in the p region, and electrons in the n region, both moving toward the p-n junction. Electrons and holes meet and recombine in the vicinity of the junction, and then release energy in the form of photons of light. The device in which light is emitted in this way is termed a *light-emitting diode* or LED. The energy separation between the top of the valence band and the bottom of the conduction band is known as the bandgap energy E_g. Since the electron and holes will settle to the band edge before recombining, the energy of the emitting photon is therefore approximately equal to E_g. The number of emitting photons per unit time is related to the number of electrons entering the junction per unit time, i/e. Its optical power P_{opt} is expressed as

$$P_{opt} = \left[\frac{energy}{unit \quad time}\right] = \left[\frac{electrons}{unit \quad time}\right]\left[\frac{photons}{electrons}\right]\left[\frac{energy}{photons}\right] = \frac{i}{e}\eta h\nu ,$$

where i is the electric current, η is the emission efficiency, h is the Plank constant ($h = 6.626\times10^{-34}$ J·sec.), ν is the frequency of the light, and e denotes the elementary charge, i.e., $e = 1.6\times10^{-19}$C. On the other hand, it has been shown that the dependence of current i on applied voltage V can be written as

$$i = i_o[\exp(\frac{eV}{\beta K_B T}) - 1],$$

where i_o is the reverse saturation current, K_B is the Boltzmann constant ($K_B = 1.38 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}), T is the absolute temperature, and β is the diode ideality factor.

Now a GaAs LED connected with a battery V_s and a load resistor R is designed to generate an optical power of 30mW, as shown in Fig. 3. The bandgap of GaAs is 1.42eV. Assume that $V_s = 3.0$ Volt, T=293°K (room temperature), $\beta = 1$, $i_o = 1.0\times10^{-4}\mu$A, and $\eta = 0.6$. Please answer the following questions:

(a) What is the corresponding emission wavelength? (20%)

(b) Please determine the required load resistance. (30%)

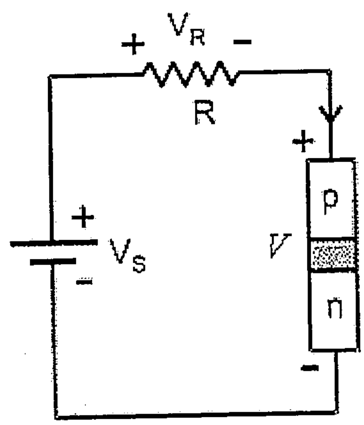

Fig. 3.