Electrostatic Fields

1. A cloud of charge is distributed with density $\rho = \rho_0(r/a)$, where ρ_0 is a constant, over a sphere volume of radius **a**.
   (a) Find the electric field intensity and the potential distribution in the region of $r < a$. (10%)
   (b) Determine the electric energy store in the system. (10%)

2. A cylindrical capacitor shown in Fig. 1 consists of an inner conductor of a radius **a** and an outer conductor whose inner radius is **b**. The region between the conductors is filled with a dielectric of non-uniform permittivity $\varepsilon = \varepsilon_0 b/r$. Assume the inner conductor is maintained at a potential V_0 and the outer conductor is grounded. Answer the following questions:
   (a) Determine the potential distribution between the conductors. (10%)
   (b) Find the expression for the capacitance of the cylindrical capacitor. (10%)

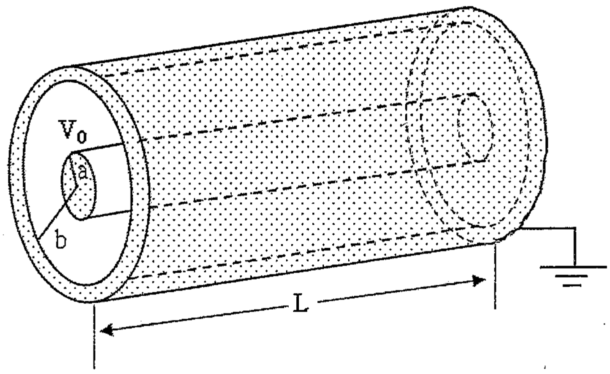

Fig. 1

3. Draw the systems of image charges that will replace the conducting boundaries that are maintained at zero potential for an infinite line charge ρ_l located midway between two large, intersecting conducting planes forming 45-degree angle. (10%)

Photo detectors

4. A PN photodiode consists of a p-doped and n-doped layer. When the reverse bias current is applied, the depletion layer widens, and the potential barrier becomes even higher than in the open-circuit case. Any incident photon that has energy larger than the bandgap may give up this energy by exciting an orbit electron from the valance band into the conduction band. Thus, in a photodiode, a photon of energy $h\nu$ is absorbed, creating an electron-hole pair. The electrons will flow out of the photodiode and into the external electrical circuit to produce a useful electric signal. It has been shown that the produced current i for a given light power P_{in} is given by

$$i = \eta \frac{e}{h\nu} P_{in},$$

where i is the electric current, η is the quantum efficiency, h is the Plank constant (h = 6.626×10^{-34} J·sec.), ν is the frequency of the light, and e denotes the elementary charge, i.e., $e = 1.6\times10^{-19}$C. The unit of i is Amp, while that of P_{in} is Watt.

Now a Silicon photodiode connected with a battery V_s and a load resistor R is designed to generate an electric current of 33.6μA, as shown in Fig. 2. The bandgap of Silicon is 1.12eV. Assume that V_s = 3.0 Volt, R = 500Ω, and η = 0.5. Please answer the following questions:

(a) The longest wavelength of the incident photon which can be absorbed by the photodiode is identified as the cutoff wavelength. What is cutoff wavelength of the incident photon? (20%)

(b) What is the required light power P_{in} for the case of question (a)? (30%)

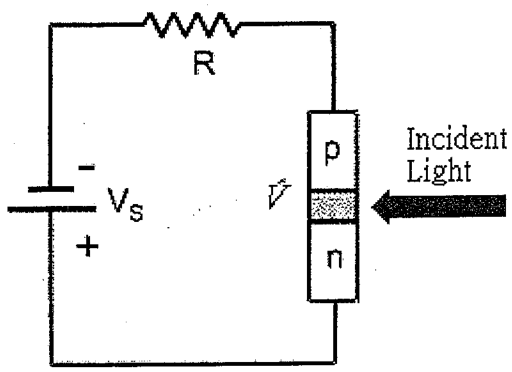

Fig. 2.