Electromagnetism

February 5, 2007

Work 4 of the 5 problems. Please put each problem solution on a separate sheet of paper and your name on each sheet.

Problem 1

The electrostatic potential on the surface of a sphere of radius R is given by

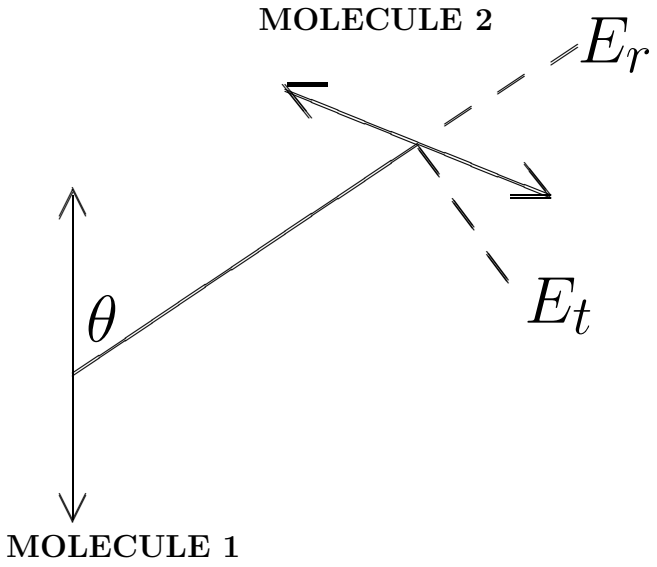
$$V(\theta, \phi) = V_0 \sin^2 \theta.$$

Solve the boundary-value problem for the sphere and find the electrostatic potential everywhere *outside* the sphere.

$$Hint: \text{Recall that} \quad P_0(\cos\theta) = 1\ ,\ P_1(\cos\theta) = \cos\theta\ ,\ P_2(\cos\theta) = \frac{3}{2}\cos^2\theta - \frac{1}{2}.$$

Problem 2

Consider two molecules; molecule 1 acts as an emitter and molecule 2 acts as a receiver. Consider molecule 1 as a classical dipole oscillator, oscillating with a frequency $\omega = 2\pi\nu$ and an amplitude A_0, so that the displacement is $A = A_0 \cos \omega t$. The charge of the oscillator (molecule 1) is q. Molecule 2 is a distance r away from molecule 1. The molecules are immersed in a medium with a refractive index n.



Show that the electrical field at the site of molecule 2 has the components

$$E_r = 2qA_0 \cos\theta \left[\frac{1}{n^2 r^3} \cos\left(\omega \left\{ t - \frac{rn}{c} \right\}\right) - \frac{\omega}{ncr^2} \sin\left(\omega \left\{ t - \frac{rn}{c} \right\}\right) \right]$$

for the field along r, and

$$E_t = qA_0 \sin\theta \left[\left(\frac{1}{n^2 r^3} - \frac{\omega^2}{c^2 r^2} \right) \cos\left(\omega \left\{ t - \frac{rn}{c} \right\}\right) - \frac{\omega}{ncr^2} \sin\left(\omega \left\{ t - \frac{rn}{c} \right\}\right) \right]$$

for the field perpendicular to r.

Problem 3

Answer all 5 parts and use diagrams where appropriate:

(A) What is the difference between electrical and thermal conductance?

(B) How do we measure the electrical conductivity of a material (draw a picture and write down the equation)?

(C) What is the difference between surface and bulk conductivity?

(D) Write down the equation for a diode which describes the current-voltage characteristics, and explain the role of the diode quality factor n.

(E) Explain what is meant by forward and reverse bias (draw diagrams of a PN or *Schottky* diode to explain).

Problem 4

If a particle of mass m and charge q is dropped from rest from a height h above the surface of the Earth and falls through a uniform magnetic field B directed parallel to the Earth's surface, neglecting atmospheric drag effects:

(A) Write down the equations of motion for the particle in terms of the cyclotron frequency $\omega = qB/m$.

(B) Solve these equations for the velocity and position of the particle as a function of time.

(C) Show that, if ω exceeds a certain value, the particle does not strike the ground.

(D) Sketch the particle trajectory in this case.

Problem 5

Derive an expression for the vector potential, A, produced by an infinitely long solenoid. (the pitch of the winding may be neglected). Give the result for both the region outside and within the solenoid.