Q.7 Ferroelectrics

Two atoms, separated by a distance r, each have polarisability α. Find the relationship between r and α for this system to be ferroelectric. Show also that the condition for a line of atoms with separation r and polarizability α to be ferroelectric is:

$$\alpha > \left(\frac{\pi \epsilon_0 r^3}{\sum_{n=1}^{\infty} n^{-3}} \right)$$

where $\sum n^{-3} = 1 + 1/8 + 1/27 + ... = 1.202$. [Hint: the dipolar field is strongest along the axis of the dipole].

Q.8 Piezoelectrics

Discuss the phenomenon of piezoelectricity. Describe an experimental method of investigating it for quartz. A lighter uses a piezoelectric crystal to produce the spark. The crystal is contained between metal plates which are struck by a hammer. The voltage developed across the plates is applied to a spark gap of breakdown potential 300 V. Calculate the minimum impact velocity of the hammer required to produce the spark, given that its mass is 0.05 kg and that it is brought to rest uniformly in a time of 5 ms.

[The piezoelectric modulus of the crystal in compression $= 3 \times 10^{-10}$ CN^{-1}. The capacitance of the crystal and plates = 10 pF.]

Q.9 Pyroelectrics

In 2005, a table-top fusion experiment was reported where deuterium nuclei were accelerated into a target using the pyroelectric effect in lithium tantalate. The pyroelectric coefficient for lithium tantalate is 5×10^{-6} CK^{-1}m^{-2}.

In the experiment a single crystal of lithium tantalate was first cooled to 240 K in a sealed chamber, filled with deuterium gas held at a fixed (low) pressure (10 mTorr). Using a heater, it was subsequently warmed up to 260 K. Estimate change in polarisation in the material arising from the heating process, assuming there are no discharges.

A grounded copper grid is placed 1 cm from the lithium tantalate crystal. Estimate the electric field and potential difference between the crystal and the copper grid, assuming $\epsilon_r(^2\text{H}) = 1$. If the breakdown field of deuterium is 10^5 Vm^{-1}Torr, explain what happens and how this produces a source of high-energy deuterium ions.

Q.10 Refractive index

Explain what is meant by the refractive index of a material. One problem with solar light harvesting is that the energy it provides is cyclic across day and night. To overcome this limitation, the government is considering investing in a scheme where alternate solar panels are covered with a 1 cm peice of material with a sufficiently high refractive index that the light takes 12 hours to pass through. What would the required refractive index of such a material be? If such a material existed, would the scheme work? [Hint: consider reflection at an interface].

Q.11 Polarised light

Describe how polarised light may be obtained by making use of *three* essentially different properties of materials. Give example of each.

Q.12 Liquid crystal displays

Explain the principles underlying liquid crystal displays and give a detailed account of one particular system.

Q.13 Optical fibres

Discuss the requirements for long-distance communication using optical fibres and discuss how far different combinations of materials and devices meet them.