Colloquiums tasks for Dielectrics- Solution

The tasks are taken from the book "Understanding Solids…"

11.1 (a) Use the relation $c = \frac{\varepsilon_0 A}{d}$

Insert: $\varepsilon_0 = 8.85419 \times 10^{-12}$ Fm^{-1}; A = 1 cm^2 = $1x10^{-4}$ m^2; d = 0.1 mm = $1x10^{-4}$ m, and obtain $8.854x10^{-12}$ F.

(b) Use the relation $c = \frac{\varepsilon_r \varepsilon_0 A}{d}$

Insert also for $\varepsilon_r = 2.3$ and obtain $2.04x10^{-11}$ F

11.2 The charge on the plates with and without an additional dielectric material can be described as:

$q = \frac{\varepsilon_0 AV}{d}$ and $q' = \frac{\varepsilon_r \varepsilon_0 AV}{d}$ respectively. Thin implies that the difference between these charges are due to the factor ε_r. This can thus be calculated by taking: $\varepsilon_r = 750 / 200 = 3.75$

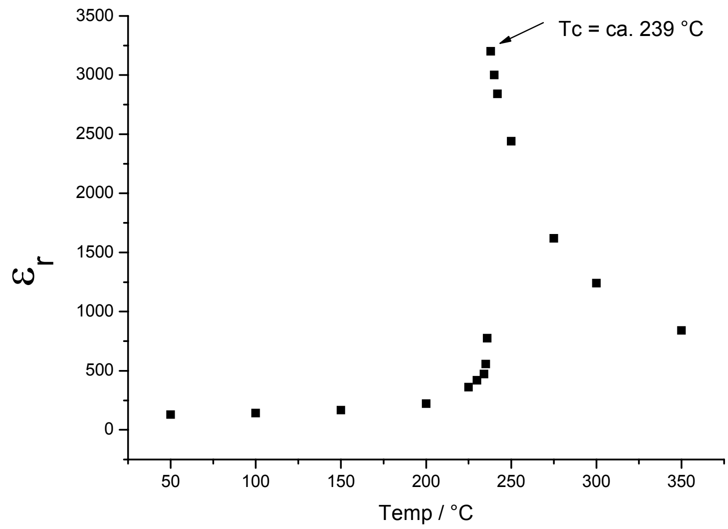
11.4 (a) Use the relation: P = q x r, giving q = P/r. In this case P = 0.5 x 10^{-30} Cm and r = 0.115 nm = 1.15 x 10^{-8} m. By inserting this on obtains q = 4.35 x 10^{-23} C (0.03e)

(b) Nitrogen is more positive since it is less electronegative than oxygen.

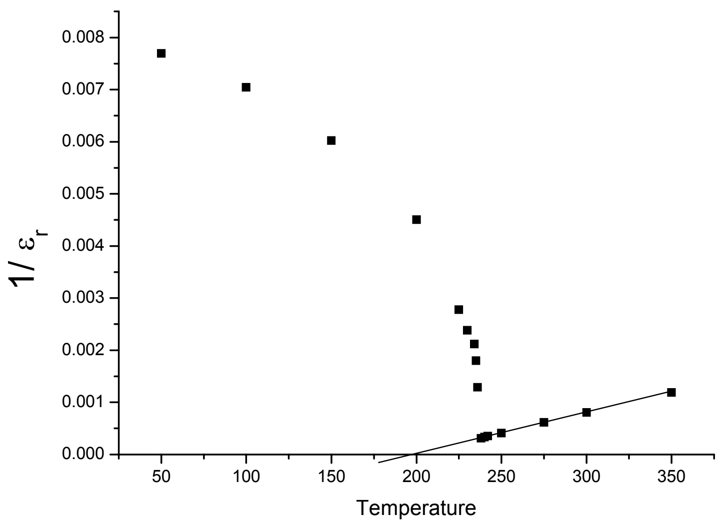
11.19 The force of 0.5 kg on that plate will be: 0.5 kg * 9.8 m s^{-2} / (0.1 x 0.05 m^2) = 980 N m^{-2}. Multiplying this by the dielectric constant 2.3 pC gives the polarization of the plate: $2.26x10^{-9}$ Cm-2

11.21 The change in polarization is found by multiplying the difference in temperature with the pyroelectric coefficient: ΔP = 100 K * 4 x 10^{-6} C m^{-2} K^{-1}= 4 x 10^{-4} Cm^{-2}.

11.22 (a)The T_c is best found by plotting ε_r vs. T and noting the temperature for the abnormal peak.

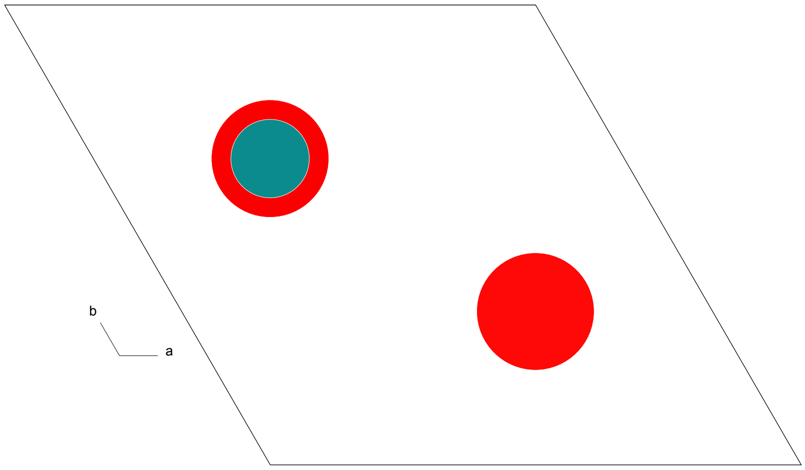


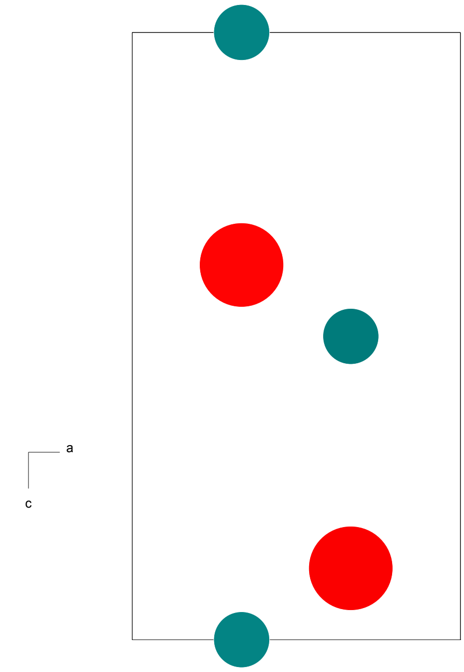
(b) The constant C can be found by plotting 1/ ε_r vs. T, and calculating the slope for temperatures over T_c.



(b) ca. 1.3×10^5 K

11.25 Zincite (zinc oxide, ZnO) has a hexagonal unit cell, with $a_0 = 0.3250$ nm, $c_0 = 0.5207$ nm and a unit cell volume of 47.63×10^{-30} m^3. The atom positions are:
Zn (1/3, 2/3, 0), (2/3, 1/3, 1/2)
O (1/3, 2/3, 0.38), (2/3, 1/3, 0.88).
There are two formula units of ZnO in the unit cell.
(a) Sketch the unit cell





(b) Estimate the maximum spontaneous polarization of ZnO, assuming that the structure is ionic.

First find the amount that the oxygen atoms are displaced by.

The oxygen is shifted by the amount: (0.389-0.375)*c = 7.2899 x 10^{-12} m.

There are two oxygens in the unitcell and their charge is of 2e each. The dipolemoment then becomes: 7.2899 x 10^{-12} m * 2 * 1.60219x10^{-19} C *2 = 4.67185 x 10^{-30} Cm.

Cell volume is 47.63 $Å^3$ = 4.763x10^{-29} m^3.

The polarization is obtained by dividing the dipolemoment by the cell volume: 4.67185 x 10^{-30} Cm / 4.763x10^{-29} m^3 = 0.098 Cm^{-2}

11.29 (a) The dipole moment can be calculated as: 4e*0.030 nm = 4 * 1.60219x10^{-19} C * 0.030x10^{-9} m = 1.92x10^{-29} Cm
(b) This polarization is divided over a volume of $a_0*a_0*c_0$ = 6.313x10^{-29} m^3. The maximum spontaneous polarization is found by dividing the dipole moment with this volume and obtain 0.30 Cm^{-2}

11.30 For a material to be ferroelectric it needs to have the possibility to change its polarization between more than one stable direction. This leads to a variation in potential energy as described in Fig. 11.15. The polarization must maintain as a finite value when an external field is switched off.

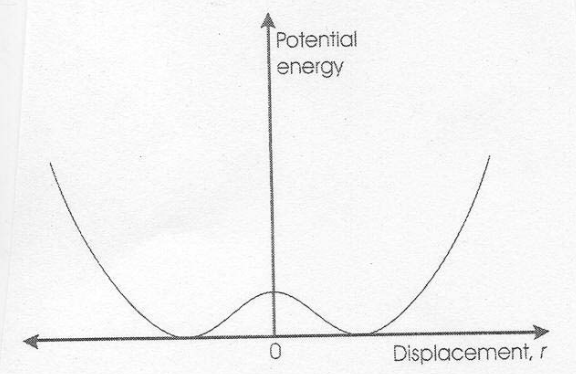


Figure 11.15 The variation of potential energy with cation displacement, $\pm r$, from the centre of a surrounding anion polyhedron

In order to have this possibility the material must adopt one of the point groups that has non centre of symmetry and not be the 432 point group. It must also show some unique polar axis.

11.31 Silica glass is an amorphous material witch is virtually isotropic. This means that any alterations in any direction in that material are likely to be cancelled out. Amorphous materials do not posses centre of symmetry since it is impossible to account for every atom and the mathematical expression of centre of symmetry fails rapidly. However, on a larger picture the material may be viewed as a very isotropic and symmetrical material since it is equally amorphous in all directions.