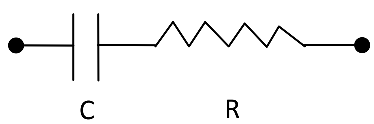
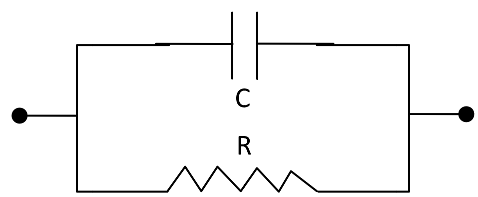
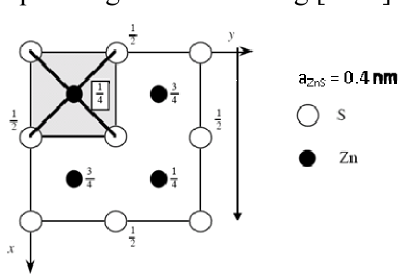
Module 4 and 5   Linear and Nonlinear Dielectric Ceramics

1. Plot the dielectric constant and loss vs frequency for two materials: Ge and ZrO_2. Briefly explain the reasons for each region in each material.
2. A 2 cm diameter and 0.25 mm thick disk of steatite was measured and found to have a capacitance of 7.2 μF and a dissipation factor of 72. Determine the following properties:
   a. Permittivity of dielectric
   b. Electric loss factor
   c. Electrical susceptibility
3. Si has an atomic radii of 110 pm. What type of mechanisms you expect in Si to contribute to its dielectric constant contribution? Calculate the dielectric constant of Si using appropriate expression. Observed value is about 11-12. Compare and comment on the difference, if any, and any reasons for such behavior.
4. A 0.5 cm thick dielectric material has a dielectric constant of 75 and loss tangent of 20. If the materials if used at 100 Hz and 1000V, calculate the power loss density in the dielectric.
5. Following are two electrical circuits (series R-C and parallel R-C). Attempt the following:





   a. Derive the expressions of the impedance and admittance of both circuits.
   b. Derive the expressions of the real and imaginary dielectric constant and loss tangent.
   c. Plot these quantities as a function of frequency.
   d. Under what conditions, would the Debye equations look similar to obtained from (b). What would be the physical meaning?
6. Plot the free energy-displacement and susceptibility *vs* temperature plots for ferroelectric Barium Titanate and schematically show the behavior across its Curie temperature.
7. Piezoelectric ZnS upon application of stress becomes non-centrosymmetric. Its (001) plan view is shown in the figure below. This crystal is subject to the equilibrium arrangement of shear stresses τ acting such that tensile stresses are along [110] and [$\bar{1}\ \bar{1}\ 0$] directions and compressive stresses of equal magnitude are along [$1\ \bar{1}\ 0$] and [$\bar{1}\ 10$] directions. Answer the following:



a. With the help of arrows, sketch on the same figure the resulting movement of S atoms keeping the Zn atoms fixed. S atoms form the coordination tetrahedra around Zn atoms located at ¼ ¼ ¼. Have the coordinates of the centre of mass (and thus centre of charge) of S atoms changed?
b. In what direction, must the Zn atom move to remain equidistant from the coordinating S atoms? Would it still be at the centre of charge of the S atoms?
c. If the Zn–S bond is ionic, or partially ionic, in what direction will the dipole moment develop?
d. At the charge-centre of a tetrahedron of S atoms around Zn in the unstressed crystal, what charge due to S must appear? Express the value in terms of charge of one S atom (-q).
e. Experimental evidence shows relatively large covalent character of Zn-S bonds in ZnS structures modifies the the magnitude of the charge on each S and Zn 'ion' to $|q| \approx 0.26.e$ where e denotes the electronic charge. Experimentally the displacement (Δl) of the Zn ion from the centre of the tetrahedron is 75 fm when $\tau = 25$ MPa. Calculate the electric polarization, P and piezoelectric coefficient, d?