Teaser Question
Basic Training in Condensed–Matter Theory
Craig Fennie; Due Friday, April 3, 2009 (try to write something for the first
one, but also try to think about the second one)

**There was a brief mention in class that a ferroelectric is also fer-
roelastic. What we mean is that at the a second order ferroelectric
phase transition, the system simultaneously undergoes a ferroelastic
transition.**

Show that Landau wont be upset with such a statement. (Using group-
theoretic arguments, one should be able to prove the above is always true but
dont worry about it for friday.) This is what is meant when we say that $\mathbf{P}$
is the primary order parameter, while η is a secondary order parameter. Said
another way that the system undergoes a proper ferroelectric transition and an
improper ferroelastic transition.

Answer:

**The electrical polarization is fundamental to the theory of insu-
lating materials (and central to the theory of dielectrics and ferro-
electrics) yet we didn't know if P was even a bulk quantity until the
early 1990's when David Vanderbilt (building on the work of Rafaelle
Resta and others) devised the Berry phase theory of electrical polari-
ation. The most surprising aspect of this theory is that P has nothing
to do with the charge density (i.e., the modulus of the wavefunction)
but rather the phase of Bloch orbitals.**

What is wrong with defining $P = \frac{1}{V} \int d\mathbf{r} \rho(r)\mathbf{r}$ for an extended system (i.e.,
Bloch system). Why is it ok for a finite system?

Answer: