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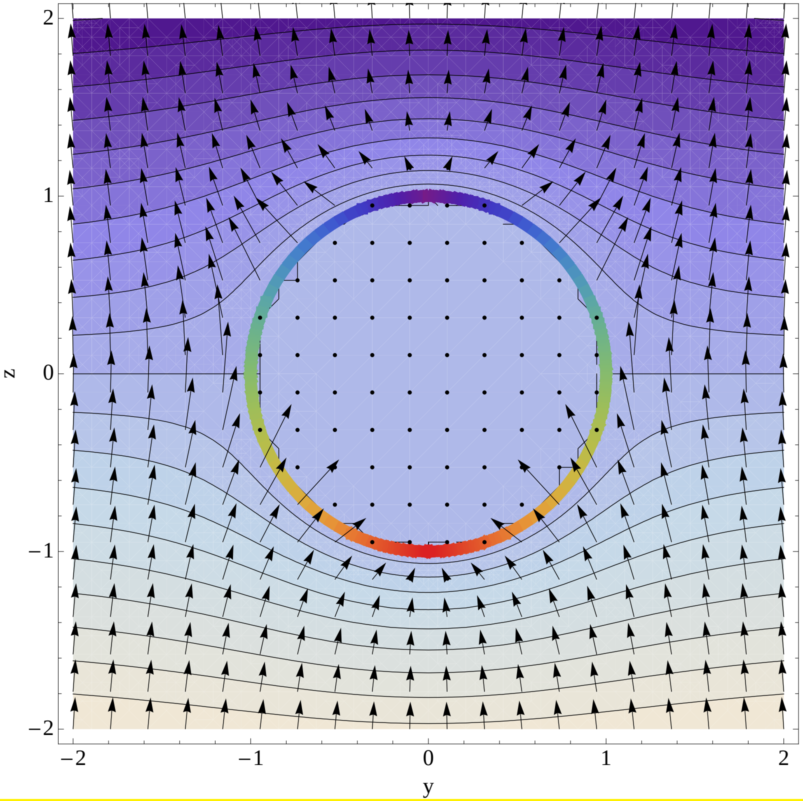
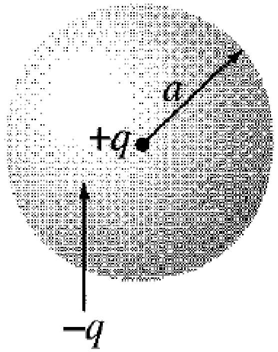
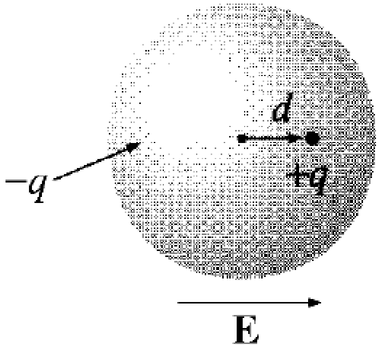


Mechanisms for Polarizing Particles

- Induced Polarization: Shift electrons and nuclei.





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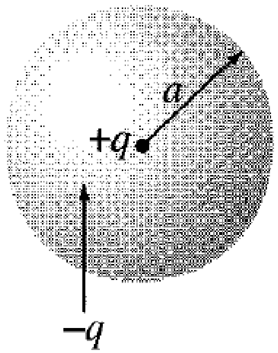
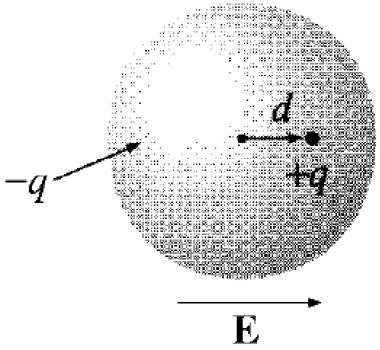
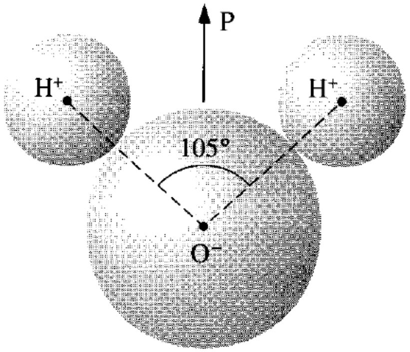
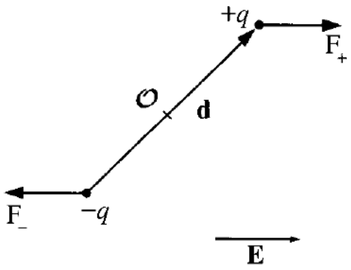




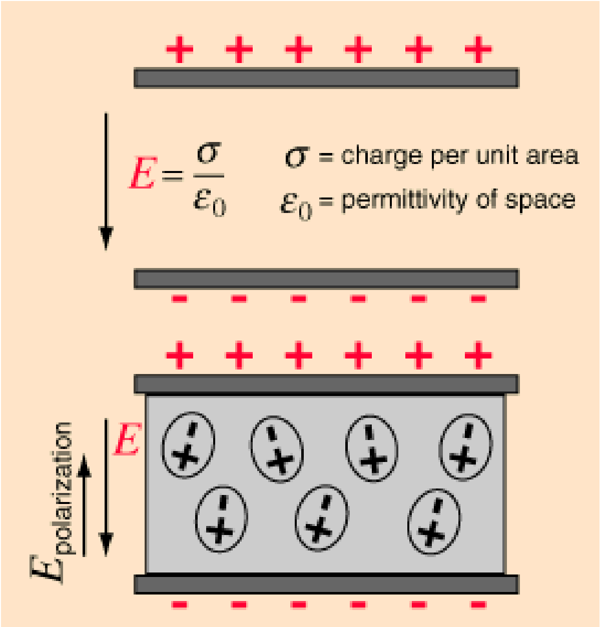
- Polar Objects: Some nuclei, molecules, *etc.* have a permanent dipole moment. They get rotated by the applied field.





What is a dielectric?

- The dielectric constant of a material measures how the material responds to an applied external electric field.
- If the atoms in the material have a dipole moment they will tend to orient themselves in the applied field so the net field in the material is reduced.
- Internal electric field reduced from the vacuum value by the dielectric constant ϵ_r.



- Dielectric are non-metallic substances (gas, liquid, or solid).
- Many practical applications like storing energy in capacitors, piezoelectric for making measurements, accumulating charge in an accelerator, *etc.*

The Problem

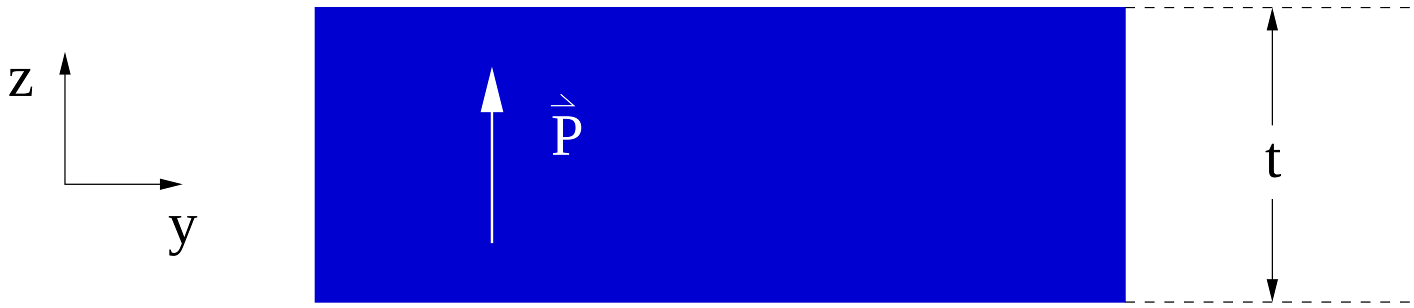
In a linear dielectric,the polarization is proportional to the field. If the material is a gas of atoms, the induced dipole moment of each one is also proportional to the applied field. What is the relationship between the atomic polarizability α and the dielectric constant ϵ_r? How well do your results agree with the data in the table below?

Gas	$\alpha/4\pi\epsilon_0 \ (10^{-30}\ m^3)$	$\epsilon_r^\dagger$
Hydrogen	0.667	1.00025
Helium	0.205	1.000065
Neon	0.396	1.00013
Argon	1.64	1.00052

An Example

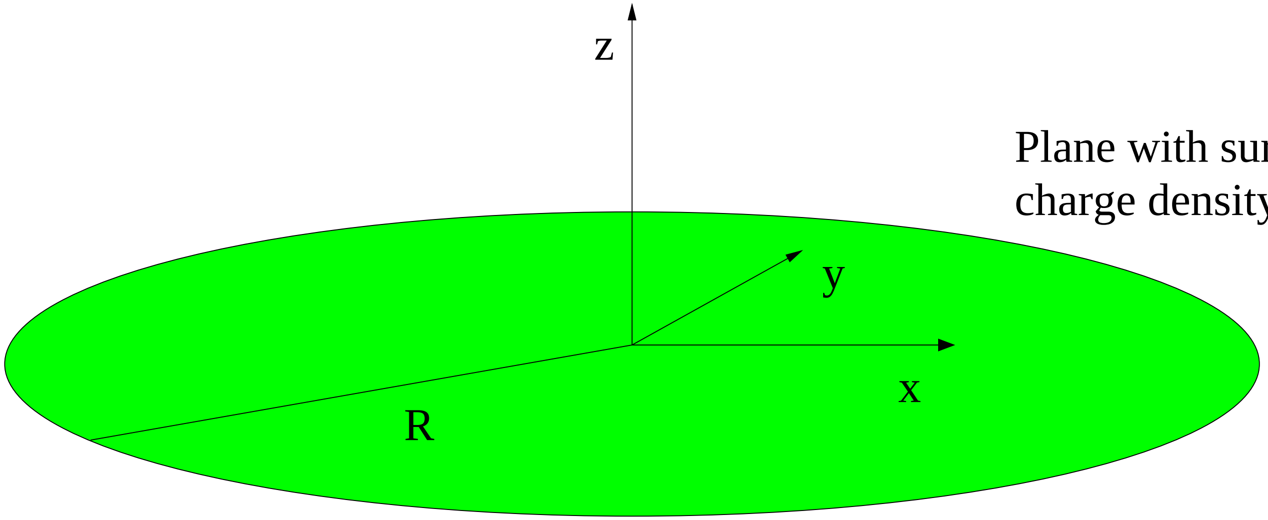
A thin, disk-shaped block of dielectric of thickness t and radius R has a uniform polarization $\vec{P} = P\hat{z}$ as shown in the figure.

1. What are the bound charges σ_b and ρ_b?
2. What is the field inside the dielectric along the axis of the disk?
3. What is the field outside the dielectric along the axis of the disk?



Problem 2.6

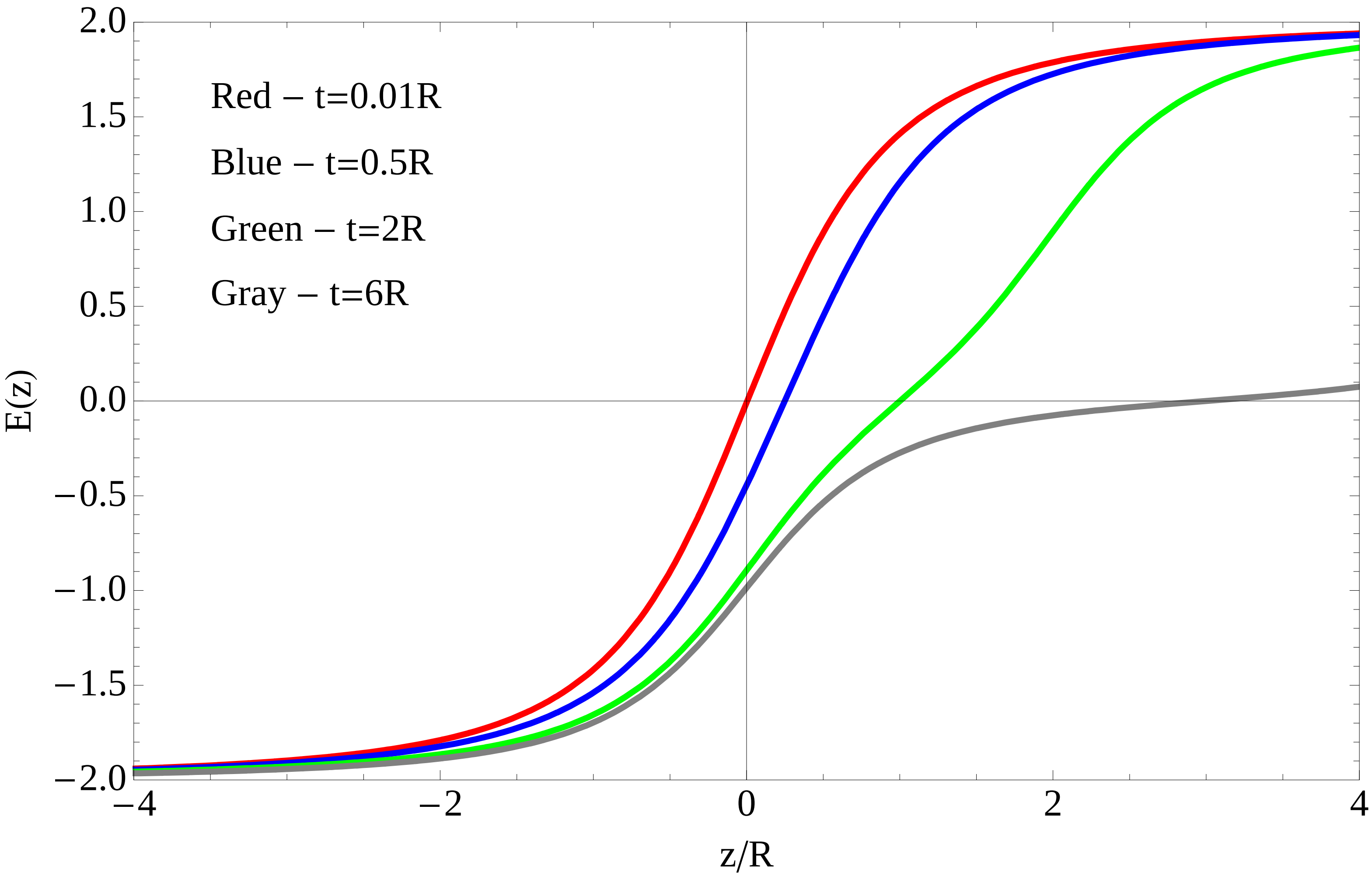
Find the electric field a distance z above the center of a flat circular disk of radius R (see figure below), which carries a uniform surface charge σ. What does your formula give in the limit $R \rightarrow \infty$? Also check the case $z >> R$.



Plane with surface
charge density σ

$$\vec{E} = \frac{1}{4\pi\epsilon_0} 2\pi\sigma z \left(\frac{1}{z} - \frac{1}{\sqrt{z^2 + R^2}} \right) \hat{z}$$

Results for the Example



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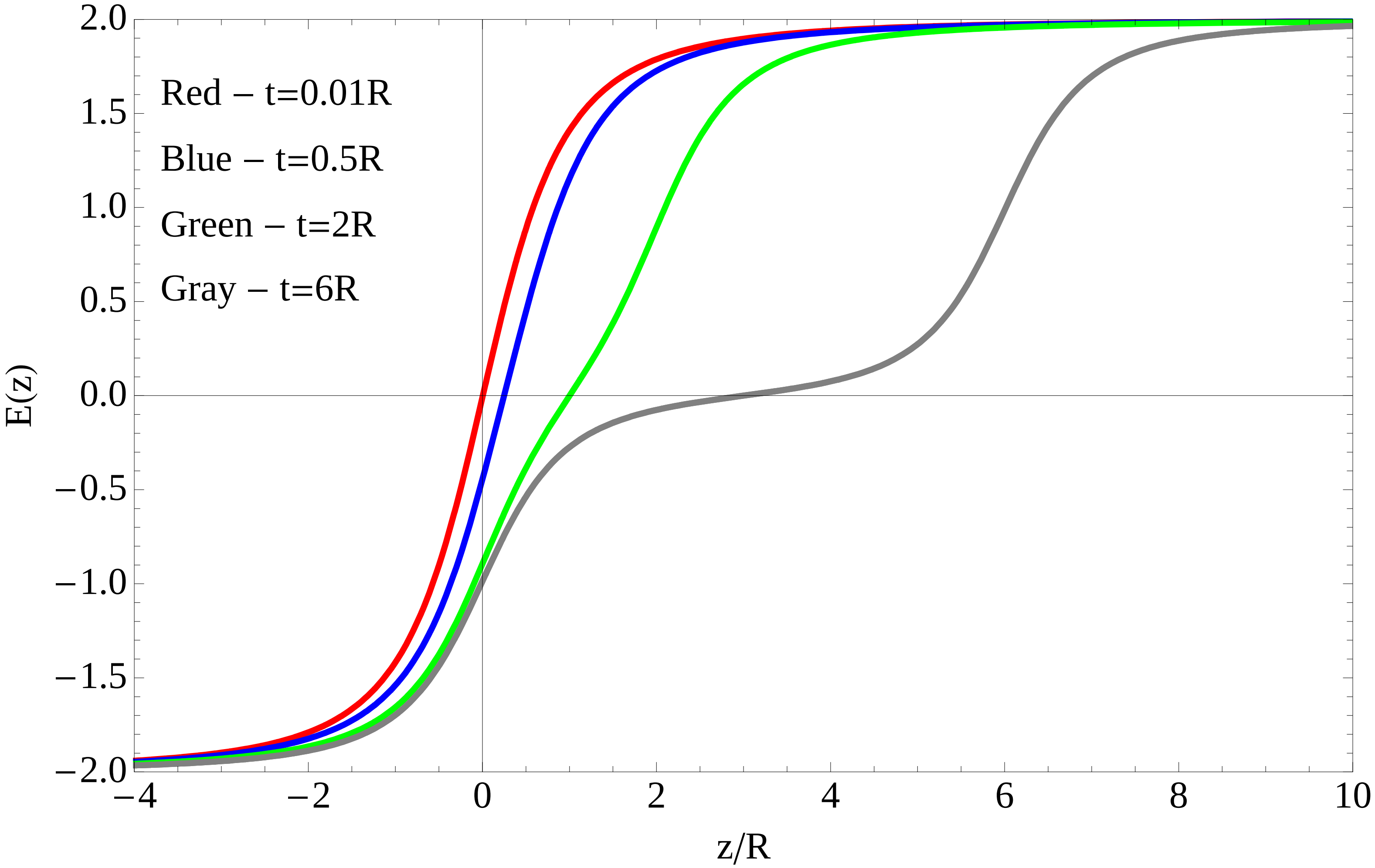


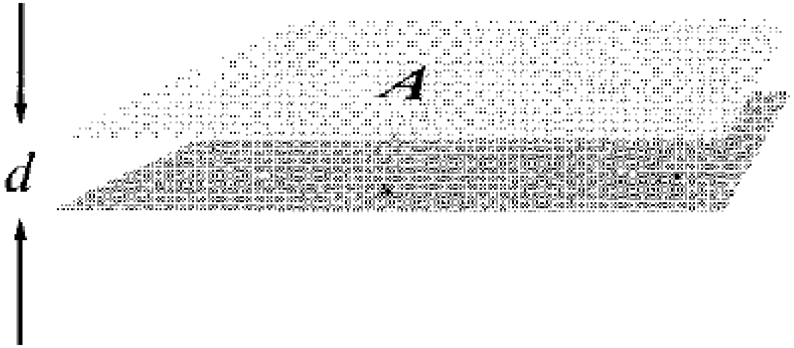
Effect of a Dielectric On a Capacitor

A capacitor is a device for storing electromagnetic energy and has many uses in electronics, power generation and storage, *etc.* A parallel plate capacitor consists of two metal surfaces of area A held a distance d apart (see figure). The capacitance C is defined as

$$C = \frac{Q}{V}$$

where Q is the amount of charge on the positive plate, $-Q$ is the amount on the negative plate, and V is the electric potential between the two plates. Assume $d^2 \ll A$.

1. What is the capacitance in terms of purely geometric parameters or constants?
2. Suppose you fill the space between the plates with an insulating material of dielectric constant ϵ_r. What happens to the capacitance?
3. How is the energy stored in the capacitor effected?



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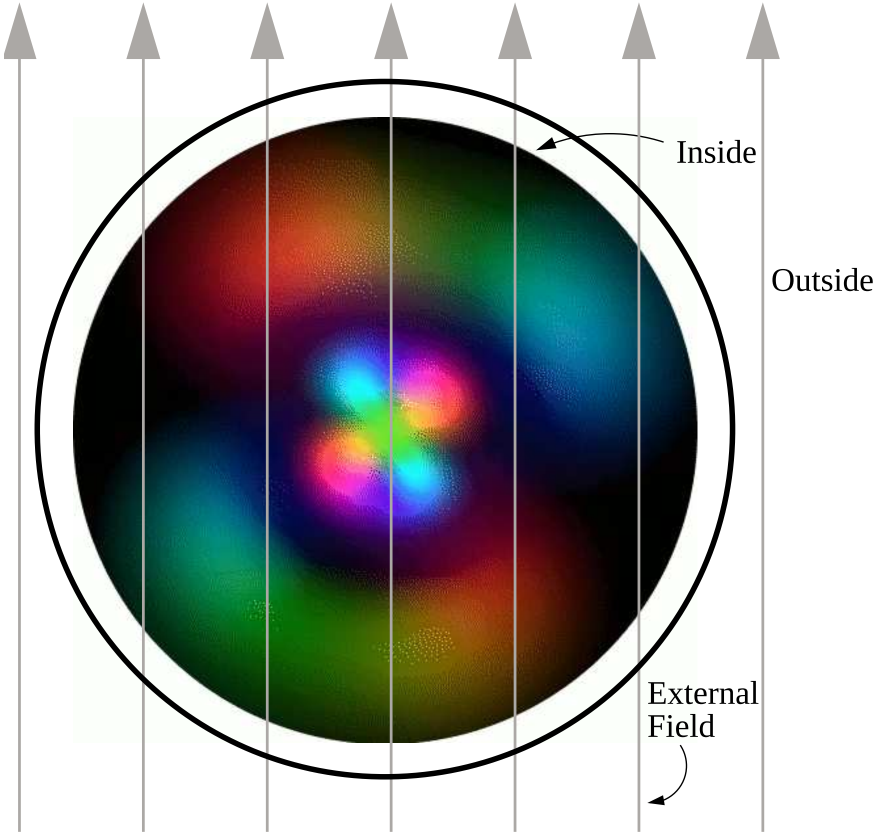
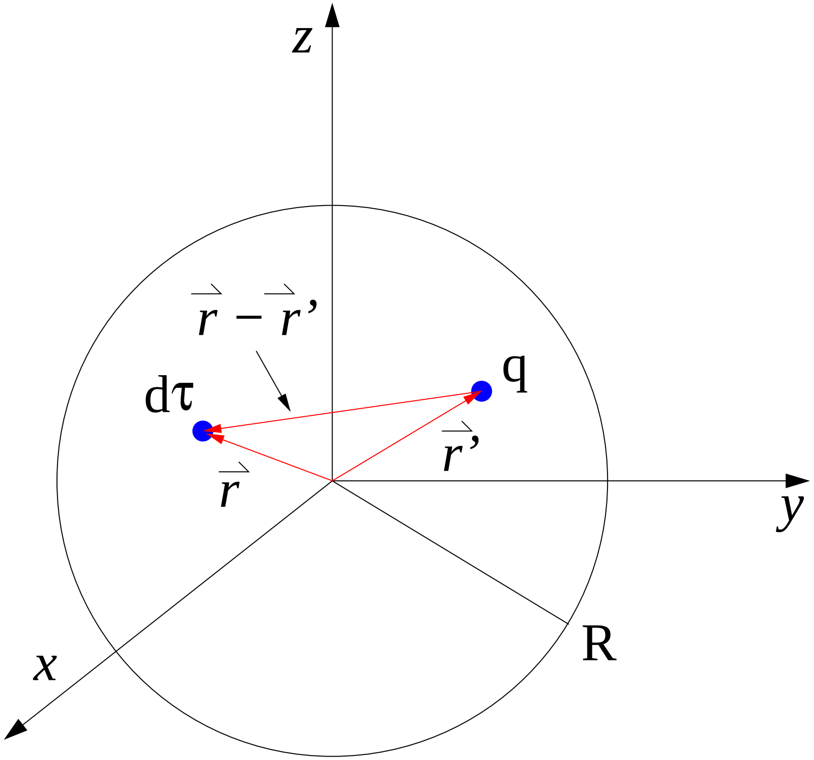
A Picture of the Atomic Environment

1. The microscopic atomic environment is one of rapid change and sensitive dependence on distance, *i.e.* the electric fields change rapidly in time and space.
2. We are interested in understanding the bulk, macroscopic behavior of materials.
3. Go after the average properties of the material and the atomic environment.
4. Divide space into the region ‘inside’ where the atom is located and the ‘outside’ which is the average product of all the other atoms.



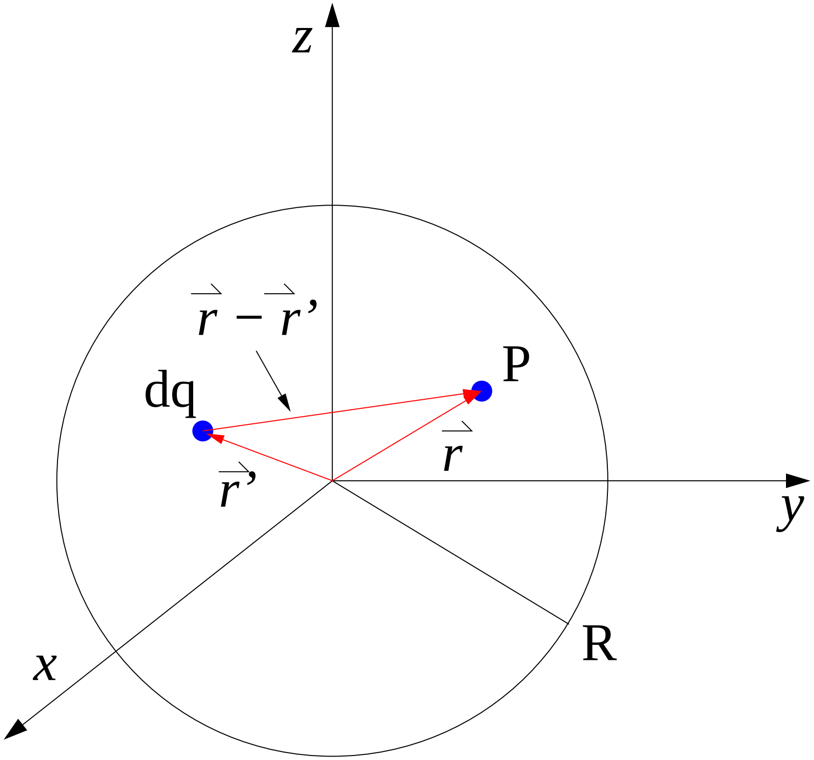
Average Field of Our Spherical Atom

What is the average field inside a sphere of radius R due to all the charge within the sphere?



The Field Inside a Uniform, Spherical, Charge Distribution

What is the electric field $\vec{E}$ at a point $\vec{r}$ inside a uniform sphere of charge with radius R, centered at the origin, and with $r < R$?



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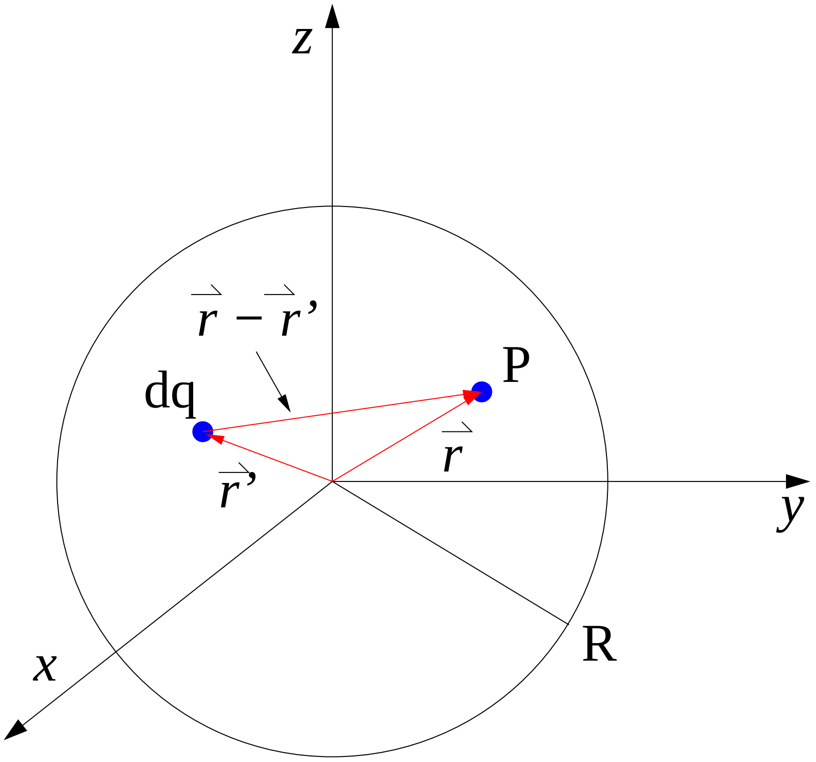
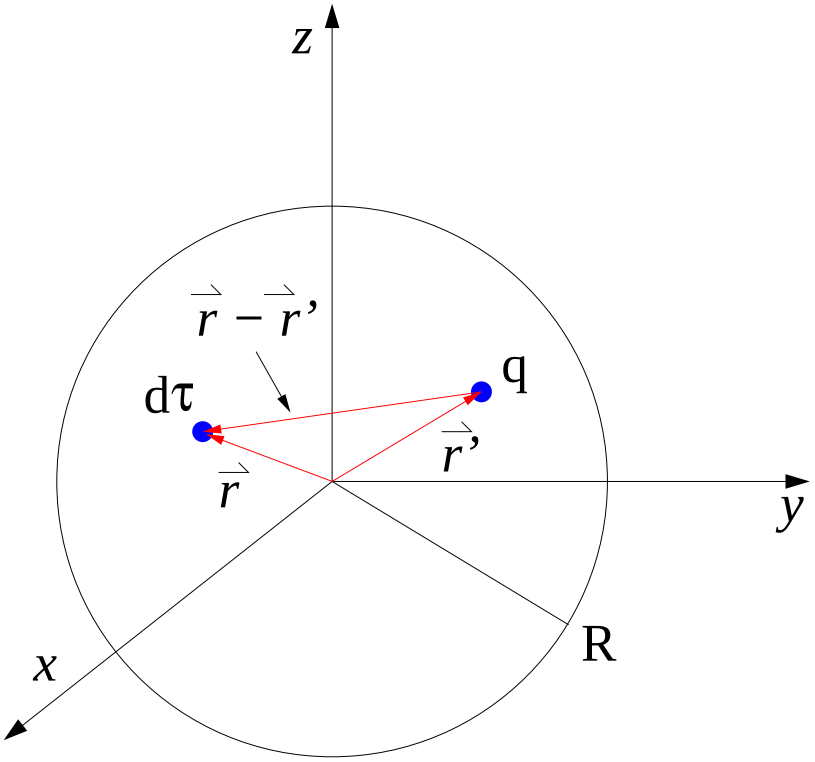
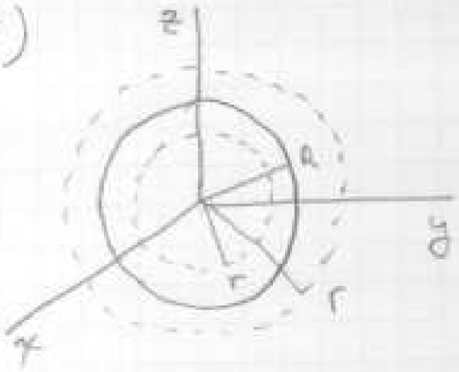




Problem 2-12

2-12)



for r > R, you get the same result as 2-11.

$$\vec{E}_{out} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$$ Same as 2.8

for r < R

$$\nabla\cdot\vec{E}_{in} = \frac{\rho}{\epsilon_0}$$

$$\int_V \nabla\cdot\vec{E}_{in}\,d\tau = \int_V \frac{\rho}{\epsilon_0}\,d\tau$$

$$\oint_S \vec{E}_{in}\cdot d\vec{A} = \frac{\rho}{\epsilon_0}\int_V d\tau$$

$$4\pi \cancel{r^2} E_{in} = \frac{\rho}{\epsilon_0}\frac{\cancel{4}}{3}\pi r^{\cancel{3}\,1}$$

$$E_{in} = \frac{\rho r}{3\epsilon_0}$$

$$\therefore\ \vec{E}_{in} = \frac{\rho r}{3\epsilon_0}\hat{r}$$ Same as 2.8

The Electromagnetic Response of Atoms

For a gas of atoms the relationship between the atomic polarizability α and the dielectric constant ϵ_r is the following.

$$\epsilon_r = \frac{1 + \frac{2N\alpha}{3\epsilon_0}}{1 - \frac{N\alpha}{3\epsilon_0}}$$

Below is a comparison of the dielectric constants calculated from the measured α's.

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* Units of $10^{-30}\ m^3$.

† For $1\ atm$, 20° C.

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IT WORKS!!

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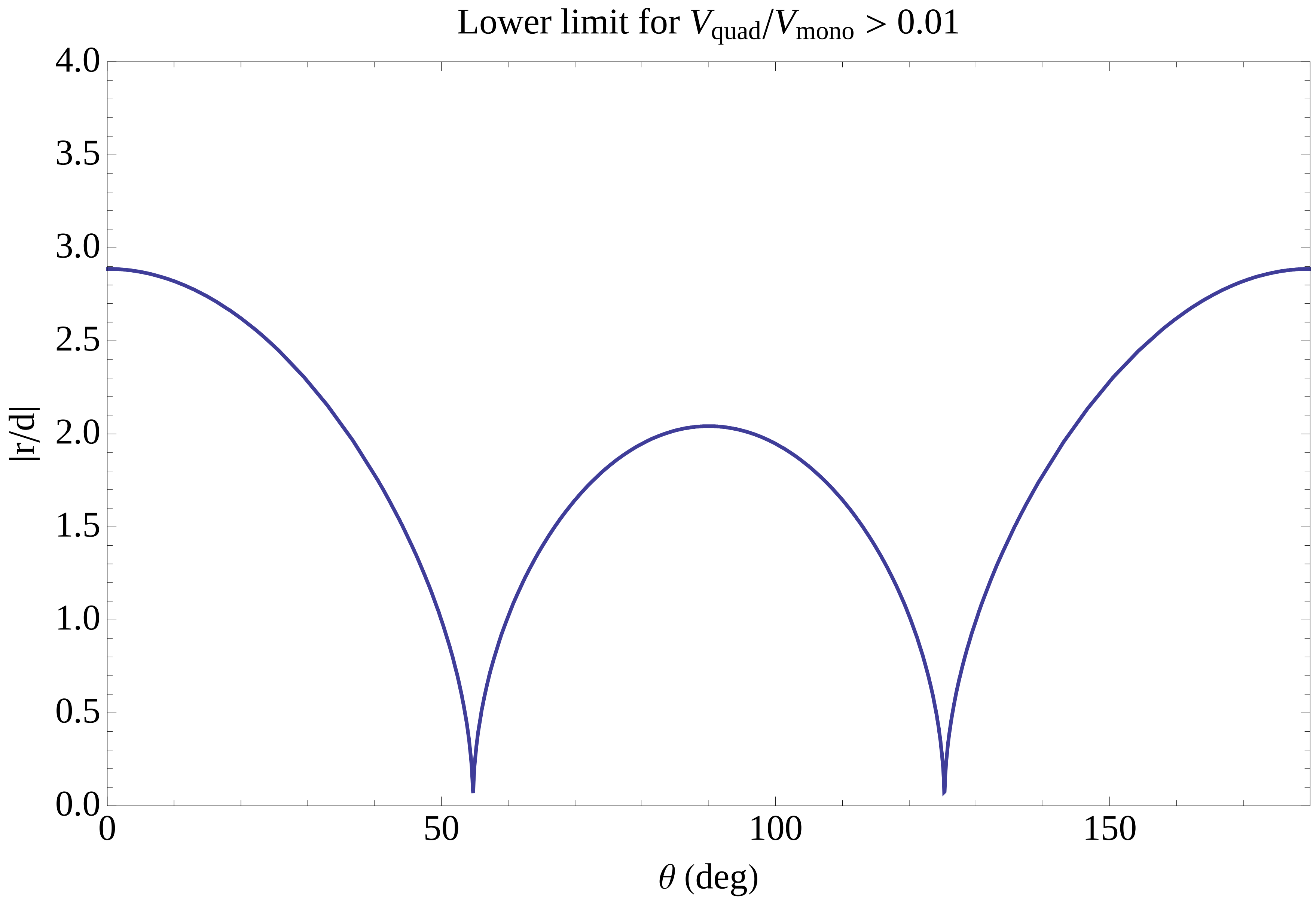
Electrostatics 4 Homework



Electrostatics 4 Homework