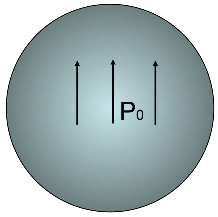
A dielectric sphere is uniformly polarized,

$$\mathbf{P} = +P_0\,\hat{z}$$

What is the surface charge density?



A) 0
B) Non-zero Constant
C) sin(θ)
D) cos(θ)
E) ??

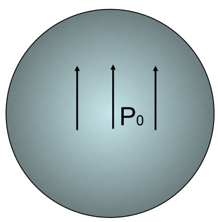
A dielectric sphere is uniformly polarized,

$$\mathbf{P} = +P_0\,\hat{z}$$

What is the surface charge density?

$$\sigma_{bound} = \mathbf{P}\cdot\hat{n}$$

$$\rho_{bound} = \nabla\cdot\mathbf{P}$$

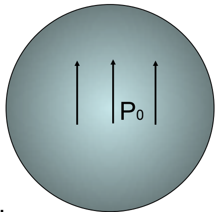


A) 0
B) Non-zero Constant
C) sin(θ)
D) cos(θ)
E) ??

In your own words, define what we mean by "free charge", and "bound charge"

4.1 alt

The sphere below (radius a) has uniform polarization $\mathbf{P}_0$ (which points in the z direction.)
What is the total dipole moment of this sphere?

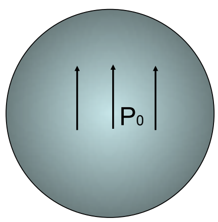


A) zero
B) $P_0 a^3$
C) $4\pi a^3 P_0/3$
D) P_0
E) None of these/must be more complicated

A dielectric sphere is uniformly polarized,

$$\mathbf{P} = +P_0\,\hat{z}$$

What is the volume charge density?



A) 0
B) Non-zero Constant
C) Depends on r, but not θ
D) Depends on θ, but not r
E) ?

If you put a dielectric in an external field $\mathbf{E}_{ext}$, it polarizes, adding a new field, $\mathbf{E}_{induced}$ (from the bound charges).
These superpose, making a total field $\mathbf{E}_{tot}$.
What is the vector equation relating these three fields?

A) $\vec{\mathbf{E}}_{tot} + \vec{\mathbf{E}}_{ext} + \vec{\mathbf{E}}_{induced} = 0$
B) $\vec{\mathbf{E}}_{induced} = \vec{\mathbf{E}}_{ext} + \vec{\mathbf{E}}_{tot}$
C) $\vec{\mathbf{E}}_{tot} = \vec{\mathbf{E}}_{ext} + \vec{\mathbf{E}}_{induced}$
D) $\vec{\mathbf{E}}_{ext} = \vec{\mathbf{E}}_{induced} + \vec{\mathbf{E}}_{tot}$
E) Something else!

4.5

We define "Electric Displacement" or "D" field: $\mathbf{D} = \varepsilon_0\mathbf{E} + \mathbf{P}$.

If you put a dielectric in an external field $\mathbf{E}_{ext}$, it polarizes, adding a new field, $\mathbf{E}_{induced}$ (from the bound charges).

These superpose, making a total field $\mathbf{E}_{tot}$.

Which of these three E fields is the "E" in the formula for D above?

A) $\mathbf{E}_{ext}$ B) $\mathbf{E}_{induced}$ C) $\mathbf{E}_{tot}$

Linear Dielectric:

$$\mathbf{P} = \varepsilon_0 \chi_e \mathbf{E}$$

χ_e is the "Electric Susceptibility

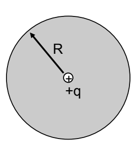
(Usually small, always positive)

4.7c-alt

We define $\mathbf{D} = \varepsilon_0\mathbf{E} + \mathbf{P}$, with

$$\oint \vec{\mathbf{D}} \cdot d\vec{a} = Q_{\text{free, enclosed}}$$

A point charge +q is placed at the center of a dielectric sphere (radius R). There are no other free charges anywhere. What is $|D(r)|$?



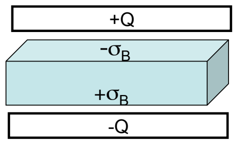
A) $q/(4\pi r^2)$ everywhere
B) $q/(4\pi\varepsilon_0 r^2)$ everywhere
C) $q/(4\pi r^2)$ for $r<R$, but $q/(4\pi\varepsilon_0 r^2)$ for $r>R$
D) None of the above, it's more complicated
E) We need more info to answer!

4.6 A very large (effectively infinite) capacitor has charge Q.
A neutral (homogeneous) dielectric is inserted into the gap (and of course, it will polarize) .
We want to find **D** *everywhere*.
Which equation would *you* head to first?

i) $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$

ii) $\oint \vec{D} \cdot d\vec{a} = Q_{free}$

iii) $\oint \vec{E} \cdot d\vec{a} = Q / \varepsilon_0$



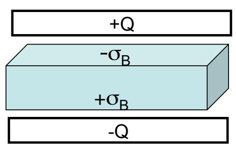
A) i B) ii C) iii
D) More than one of these would work OK.

4.6 A very large (effectively infinite) capacitor has charge Q.
A neutral <u>linear</u> dielectric is inserted into the gap (and of course, it will polarize) . We want to find **D** *everywhere*.
Which equation would *you* head to first?

i) $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$

ii) $\oint \vec{D} \cdot d\vec{a} = Q_{free}$

iii) $\oint \vec{E} \cdot d\vec{a} = Q / \varepsilon_0$



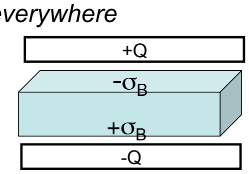
A) i B) ii C) iii
D) More than one of these would work OK.

4.6 b An ideal (large) capacitor has charge Q.
A neutral dielectric is inserted into the gap (and of course, it will polarize)
We want to find **E** *everywhere*

(i) **D** = ε_0 **E** + **P**

(ii) $\oiint \mathbf{D} \bullet d\vec{\mathbf{A}} = Q_{free}$

(iii) $\oiint \vec{\mathbf{E}} \bullet d\vec{\mathbf{A}} = Q/\varepsilon_0$

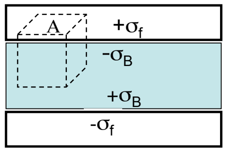


Which equation would *you* go to first?
A) i B) ii C) iii
D) Your call: *more* than 1 of these would work!
E) *Can't* solve, unless know the dielectric is linear!

MD8-4

An ideal (large) capacitor has charge Q.
A neutral linear dielectric is inserted into the gap.
We want to find **D** in the dielectric.

$$\oint \vec{D} \cdot d\vec{a} = Q_{free}$$



For the Gaussian pillbox shown, what is Qfree(enclosed)?

A) $\sigma_f A$ B) $-\sigma_B A$ C) $\sigma_f A - \sigma_B A$
D) $\sigma_f A + \sigma_B A$ E) Something else

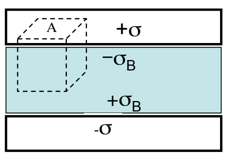
What is |**D**| in the dielectric?

A) σ_f B) $2\sigma_f$ C) $\sigma_f / 2$
D) $\sigma_f + \sigma_b$ E) Something else

MD8-4

An ideal (large) capacitor has charge Q.
A neutral linear dielectric is inserted into the gap.
We want to find **D** in the dielectric.

$$\oiint \vec{D} \cdot d\vec{a} = Q_{free}$$



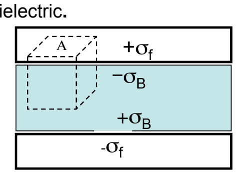
For the Gaussian pillbox shown, what is $Q_{free,enclosed}$?

A) σA B) $-\sigma_B A$ C) $(\sigma - \sigma_B)A$
D) $(\sigma + \sigma_B)A$ E) Something else

MD8-4

An ideal (large) capacitor has charge Q.
A neutral linear dielectric is inserted into the gap.
We want to find **D** in the dielectric.

$$\oiint \vec{D} \cdot d\vec{a} = Q_{free}$$



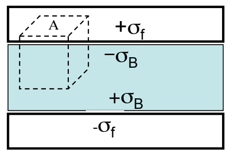
For the Gaussian pillbox shown, what is $Q_{free,enclosed}$?

A) $\sigma_f A$ B) $-\sigma_B A$ C) $(\sigma_f - \sigma_B)A$
D) $(\sigma_f + \sigma_B)A$ E) Something else

MD8-4

An ideal (large) capacitor has charge Q.
A neutral linear dielectric is inserted into the gap.
We want to find **D** in the dielectric.

$$\oiint \vec{D} \cdot d\vec{a} = Q_{free}$$



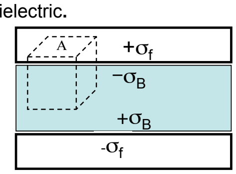
Is D zero INSIDE the metal?
(i.e. on the top face of our cubical Gaussian surface)

A) It must be zero in there
B) It depends
C) It is definitely NOT zero in there…

MD8-4

An ideal (large) capacitor has charge Q.
A neutral linear dielectric is inserted into the gap.
We want to find **D** in the dielectric.

$$\oiint \vec{D} \cdot d\vec{a} = Q_{free}$$



What is |**D**| in the dielectric?

A) σ_f B) $2\sigma_f$ C) $\sigma_f / 2$
D) $\sigma_f + \sigma_b$ E) Something else

Linear Dielectric:

$$\mathbf{P} = \varepsilon_0 \chi_e \mathbf{E}$$

χ_e is the “Electric Susceptibility”

$$\mathbf{D} = \varepsilon_0 \mathbf{E} + \mathbf{P} = \varepsilon_0 \mathbf{E} + \varepsilon_0 \chi_e \mathbf{E}$$

$$= \varepsilon_0 (1 + \chi_e) \mathbf{E}$$

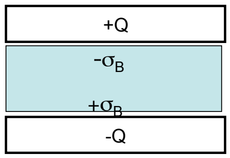
$$\equiv \varepsilon_0 \varepsilon_r \mathbf{E}$$

ε_r is the *dielectric constant*

$\varepsilon \equiv \varepsilon_0 \varepsilon_r$ is the *permittivity*

4.6d

An ideal (large) capacitor has charge Q.
A neutral linear dielectric is inserted into the gap.
Now that we have **D** in the dielectric,
what is **E** inside the dielectric ?



A) **E** = **D** $\varepsilon_0 \varepsilon_r$
B) **E** = **D**/$\varepsilon_0\varepsilon_r$
C) **E** = **D** ε_0
D) **E** = **D**/ε_0
E) Not so simple! Need another method