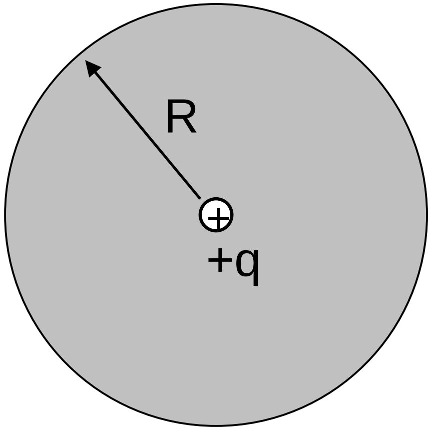
ELECTRIC DISPLACEMENT

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

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

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

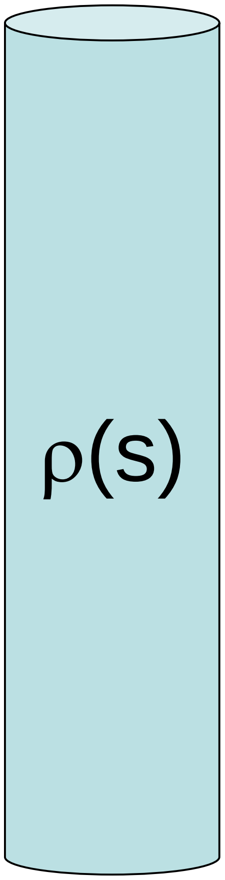
C) $q/(4\pi r^2)$ for $r<R$, but $q/(4\pi \varepsilon_0 r^2)$ for $r>R$

D) None of the above, it's more complicated

E) We need more info to answer!

A solid non-conducting dielectric rod has been injected ("doped") with a fixed, known charge distribution $\rho(s)$. (The material responds, polarizing internally)

When computing D in the rod, do you treat this $\rho(s)$ as the "free charges" or "bound charges" ?



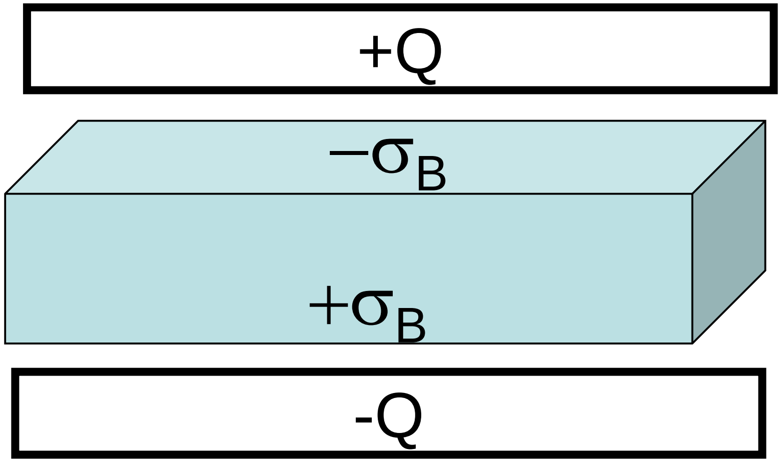
A) "free charge"
B) "bound charge"
C) Neither of these - $\rho(s)$ is some combination of free and bound
D) Something else.

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) $\vec{D} = \epsilon_0 \vec{E} + \vec{P}$

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

iii) $\oint \vec{E} \cdot d\vec{a} = Q / \epsilon_0$



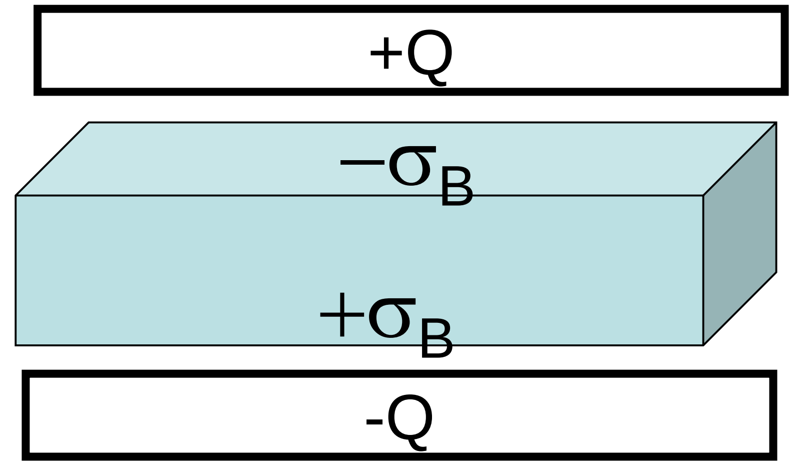
A) i B) ii C) iii
D) More than one of these would work OK.

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

(ii) $\oint \mathbf{D} \cdot d\mathbf{A} = Q_{free}$

(iii) $\oint \mathbf{E} \cdot d\mathbf{A} = Q/\varepsilon_0$



Which equation would *you* go to first?

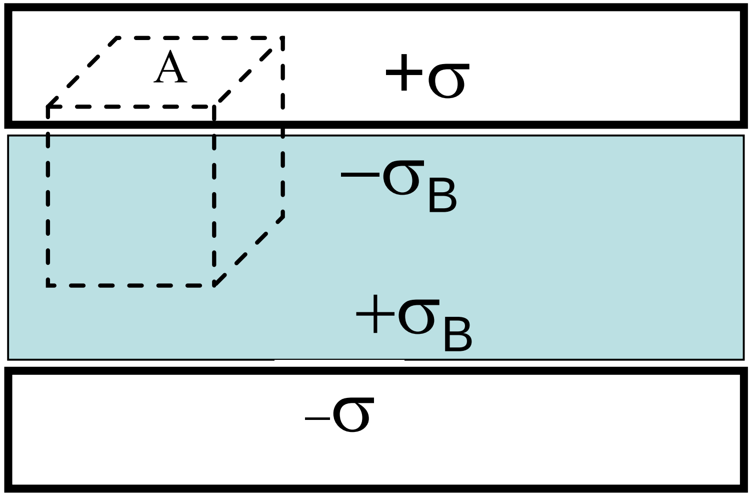
A) i B) ii C) iii

D) Your call: *more* than 1 of these would work!

E) *Can't* solve, unless know the dielectric is linear!

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

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

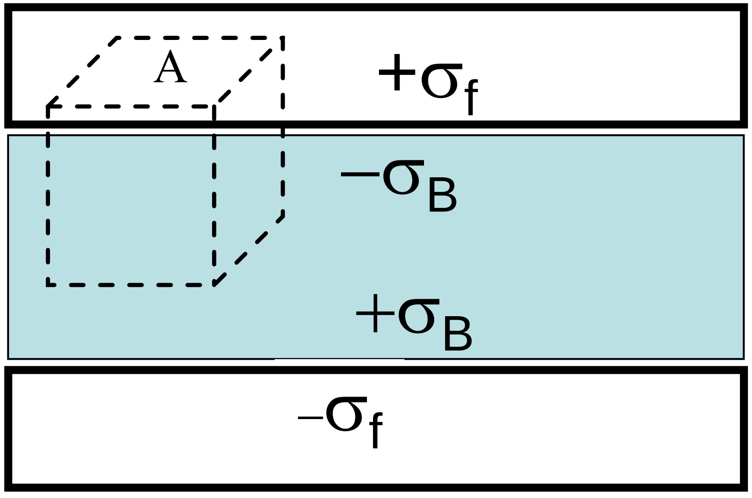


For the Gaussian pillbox shown, what is $Q_{free,enclosed}$?

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

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

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

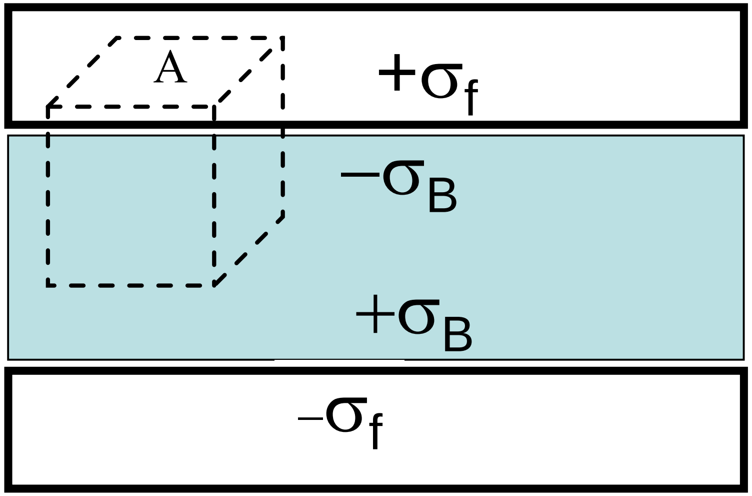


Is D zero INSIDE the metal?
(i.e. on the top face of our cubical Gaussian surface)

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

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

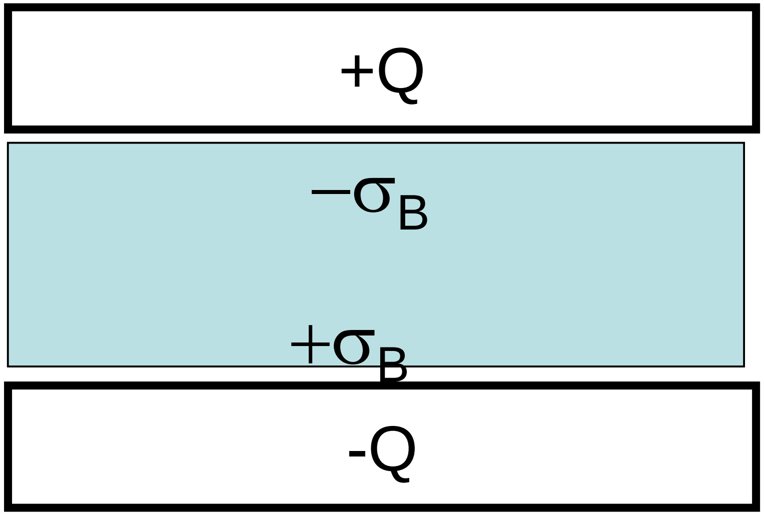
B) $2\sigma_f$

C) $\sigma_f / 2$

D) $\sigma_f + \sigma_b$

E) Something else

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**/$\varepsilon_0\varepsilon_r$

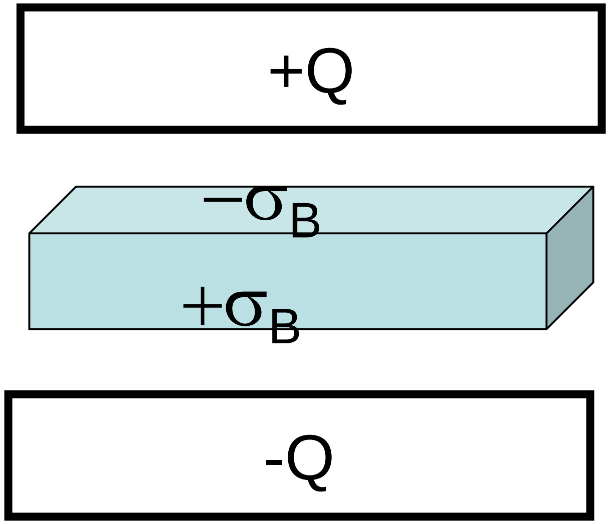
C) **E** = **D** ε_0

D) **E** = **D**/ε_0

E) Not so simple! Need another method

An ideal (large) capacitor has charge Q. A neutral *linear* dielectric is inserted into the gap (with given dielectric constant)

Where is E discontinuous?



i) near the free charges on the plates

ii) near the bound charges on the dielectric surface

A) i only

B) ii only

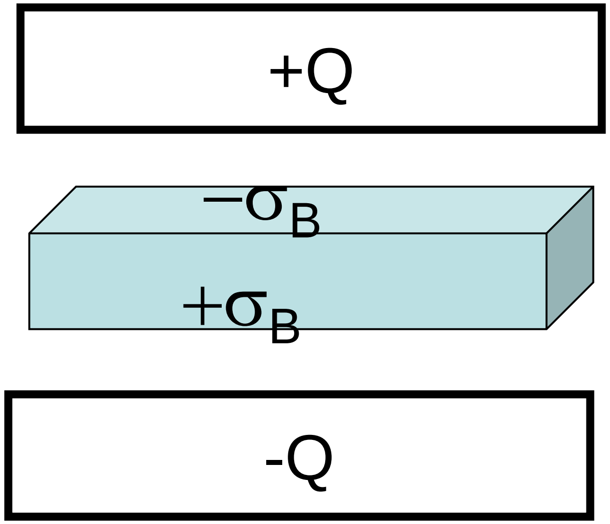
C) both i and ii (but nowhere else)

D) both i and ii but also other places

E) none of these/other/???

An ideal (large) capacitor has charge Q. A neutral *linear* dielectric is inserted into the gap (with given dielectric constant)

Where is D discontinuous?



i) near the free charges on the plates

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A) i only B) ii only

C) both i and ii (but nowhere else)

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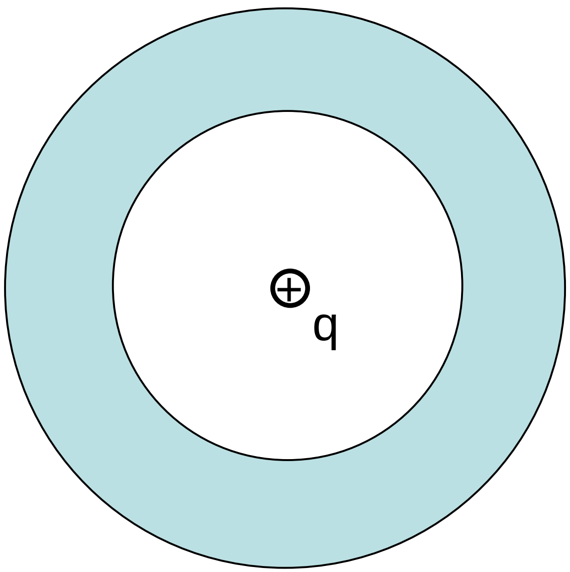
E) none of these/other/???

A point charge +q is placed at the center of a neutral, linear, homogeneous, dielectric teflon shell.
Can D be computed from its divergence?

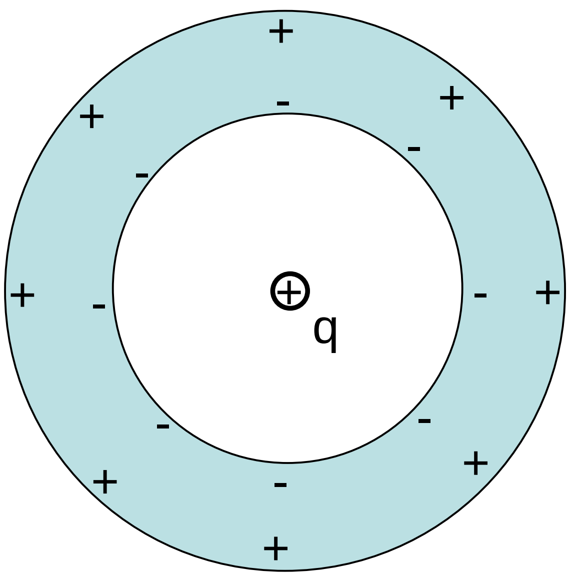
$$\oint \vec{D} \cdot d\vec{a} = Q_{free}$$



A) Yes
B) No
C) Depends on other things not given

A point charge +q is placed at the center of a neutral, linear, homogeneous dielectric teflon shell.
The shell polarizes due to the point charge.
Is the curl of the polarization **P** zero everywhere?

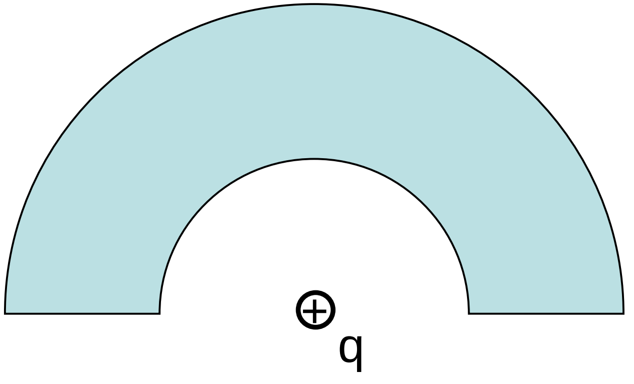
$$\oint \vec{P} \cdot d\vec{l} = 0 \quad \text{for every possible loop?}$$



A) Yes
B) No
C) Depends on other things not given

A point charge +q is placed at the center of a neutral, linear, dielectric **hemispherical** shell.
Can D be computed from its divergence?

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

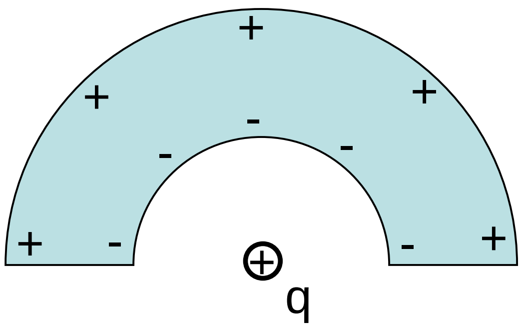


A) Yes
B) No
C) Depends on the inner radius of the dielectric.

A point charge +q is placed at the center of a neutral, linear, dielectric shell. The shell polarizes due to the point charge.

Is the curl of the polarization **P** zero everywhere?

$$\oint \vec{P} \cdot d\vec{l} = 0 \quad \text{for every possible loop?}$$



A) Yes
B) No
C) Depends on the inner radius of the dielectric.