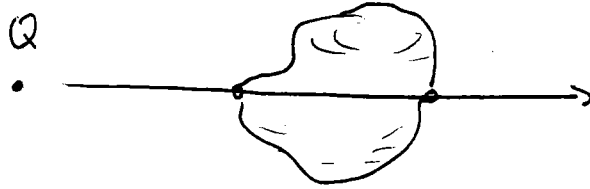


Consider Q outside



A line of force entering
also leaves

Gauss's Law

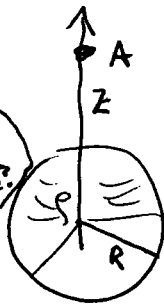
$$\int_{\text{surf}} \vec{E} \cdot d\vec{A} = \frac{1}{4\pi\epsilon_0} 4\pi Q_{\text{inside}} = \frac{1}{\epsilon_0} Q_{\text{inside}}$$

Also one of Maxwell's equations

Why do you care?

One can use Gauss's law + Symmetry to solve for \vec{E}
Almost Trivially

What is symmetry?
What Gaussian surface do I choose?
 $\Rightarrow \infty$ line charge
 $\Rightarrow \infty$ plane
 \Rightarrow Sphere



recall our awful example of Field outside
Sphere of uniform charge density

consider $r > R$

$$\Phi = \frac{Q_{\text{inside}}}{\epsilon_0} = \int \vec{E} \cdot d\vec{A} = |\vec{E}| \int dA = |\vec{E}| 4\pi r^2$$

$$|\vec{E}| = \frac{Q_{\text{inside}}}{4\pi\epsilon_0 r^2}$$

same as pt charge w/ $q = Q_{\text{inside}}$

$$Q_{\text{inside}} = \frac{4}{3}\pi R^3 \rho$$

$$|\vec{E}|_{r > R} = \frac{\frac{4}{3}\pi R^3 \rho}{4\pi\epsilon_0 r^2} = \frac{R^3 \rho}{3\epsilon_0 r^2} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

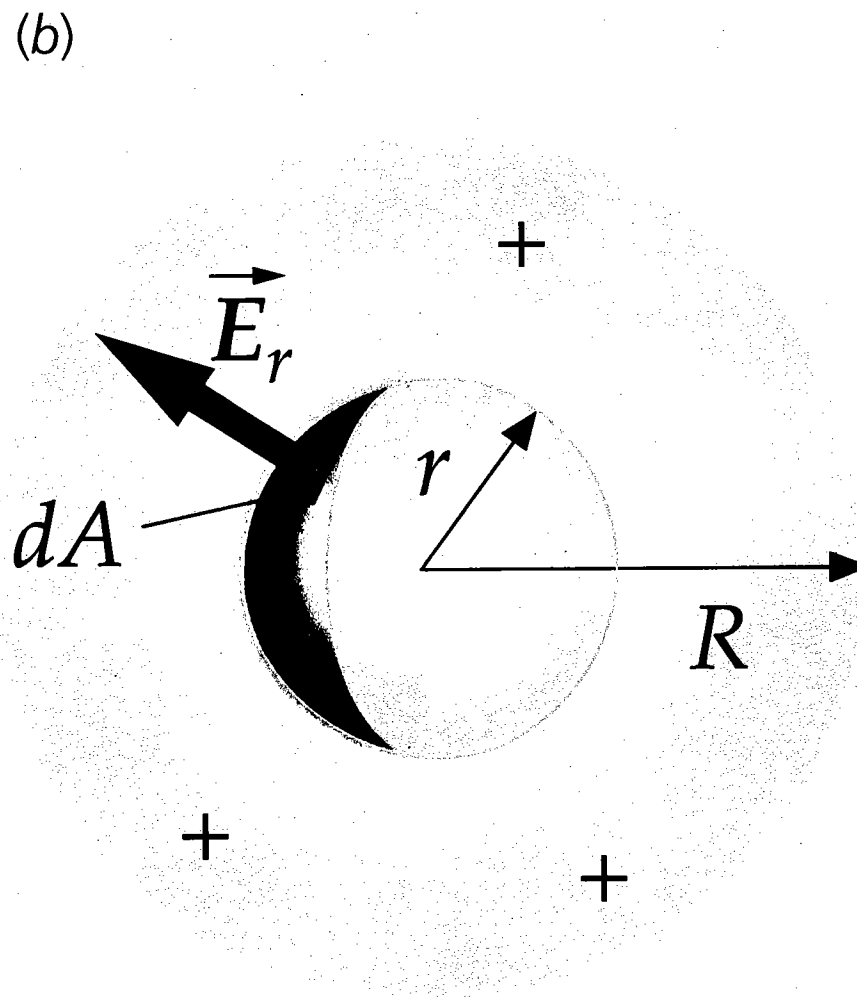
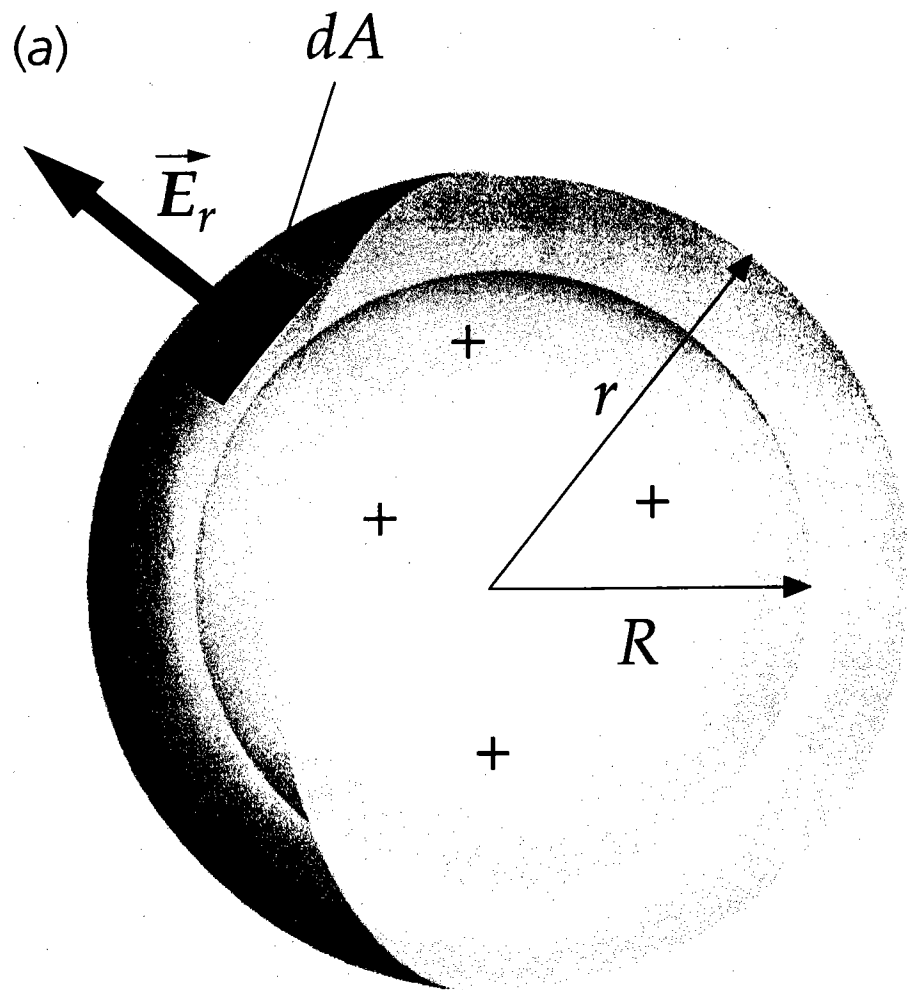
by symmetry E is in \hat{r} direction

Transparency 8

Figure 23-23, page 704

Gaussian surface outside a spherical shell (left) and inside a spherical shell (right)

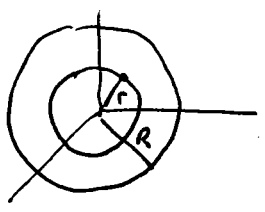
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So
$$\vec{E} \quad r > R = \frac{\rho R^3}{3\epsilon_0 r^2} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \quad r > R$$

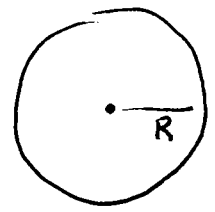
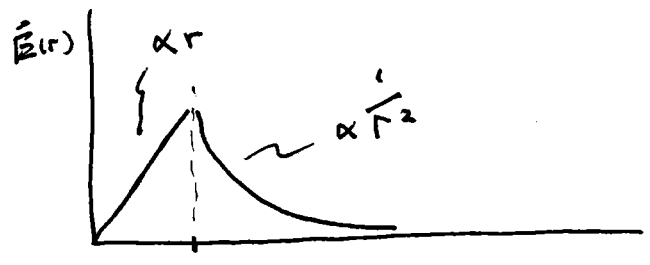
Suppose $r \leq R$

$$|\vec{E}| = \frac{Q_{\text{inside}}}{4\pi\epsilon_0 r^2}$$



$$Q_{\text{inside}} = \rho \frac{4}{3} \pi r^3$$

$$\vec{E} = \frac{\rho \frac{4}{3} \pi r^3}{4\pi\epsilon_0 r^2} = \frac{\rho r}{3\epsilon_0} = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^3} r \quad r \leq R$$



do Telegram

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 60 SHEETS ENVELOPE 2 SQUARE
 100 SHEETS ENVELOPE 5 SQUARE
 200 SHEETS ENVELOPE 5 SQUARE
 100 SHEETS ENVELOPE 5 SQUARE
 200 RECYCLED WHITE 5 SQUARE
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 Made in U.S.A.

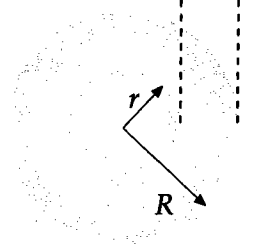
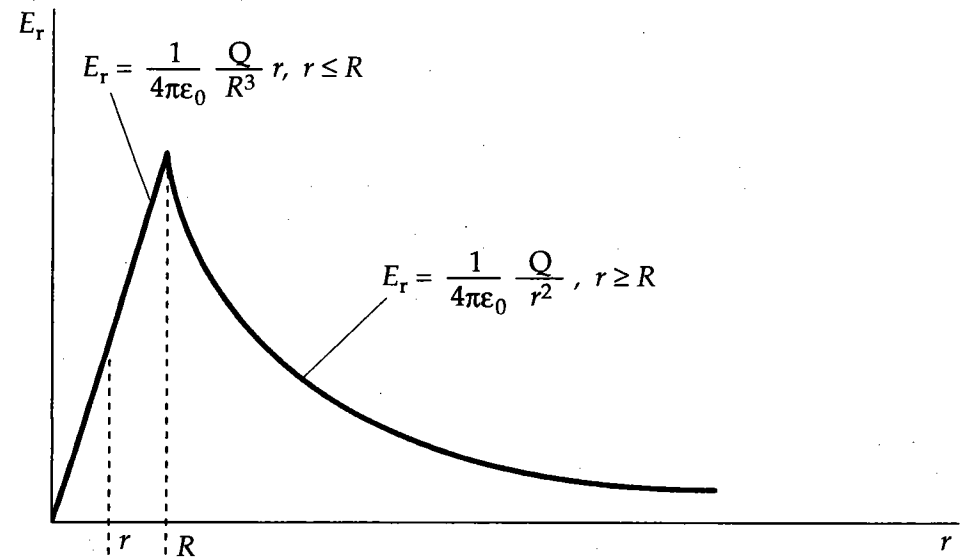
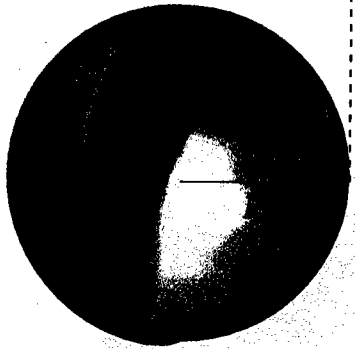
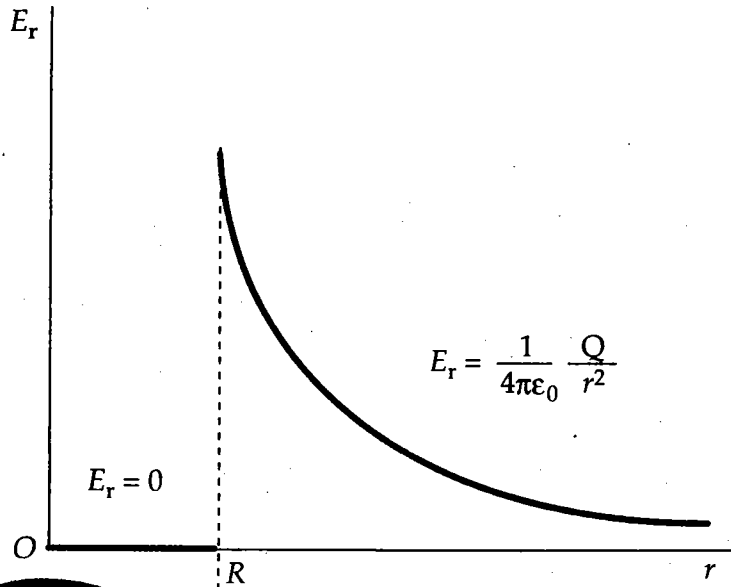
National Brand

Transparency 10

Figure 23-21, page 702; Figure 23-24, page 705

E due to a spherical shell of charge (left) and due to a solid sphere of charge (right)

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P114 Telegram:

\vec{E} can be calculated directly from ρ (or λ , or Q .)

$$\vec{E} = \int \frac{k \rho}{r^2} \hat{r}$$

often This is hard

Use Gauss's Law when symmetry allows
 $|\vec{E}|$ to be Moved out of integral

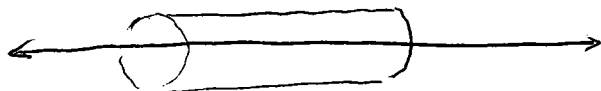
$$\int \vec{E} \cdot d\vec{a} = \frac{Q}{\epsilon_0} \rightarrow |\vec{E}| \int dA = \frac{Q}{\epsilon_0}$$

Symmetries often seen

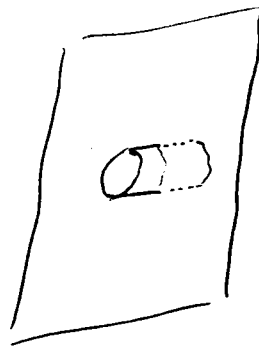


spherical

spherical
surface



line \rightarrow cylindrical
surface



Plane - pillbox

cylindrical
surface

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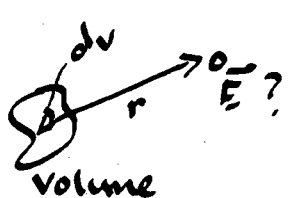
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Made in U.S.A.

\vec{E} calculated directly from charge distribution

$$\vec{E} = \int \frac{k dq \hat{r}}{r^2}$$

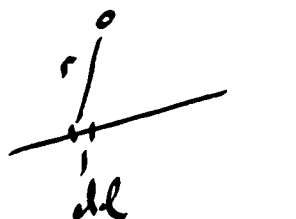
Volume



A diagram showing a small volume element dV within a larger volume. A vector \vec{r} points from the volume element to a point labeled $\vec{E}?$. The word "Volume" is written below the diagram.

$$\vec{E} = \int \frac{k \rho dV \hat{r}}{r^2}$$

line



A diagram showing a small line element dl on a line. A vector \vec{r} points from the line element to a point. The word "line" is written above the diagram.

$$\vec{E} = \int \frac{k \lambda dl \hat{r}}{r^2}$$

surface ... etc

This is hard !!

Gauss's law allows one to calculate \vec{E} in a much easier way if symmetry allows and you choose the right Gaussian surface

$$\int_{\text{Gaussian Surf}} \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\epsilon_0}$$

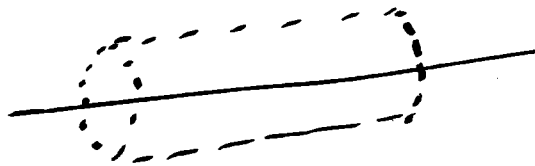
Look at symmetry of charge distribution and
choose Gaussian surface so that
 $\vec{E} \cdot d\vec{A}$ is easy to evaluate

Examples

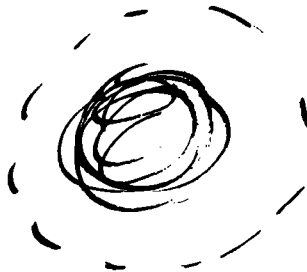
Point



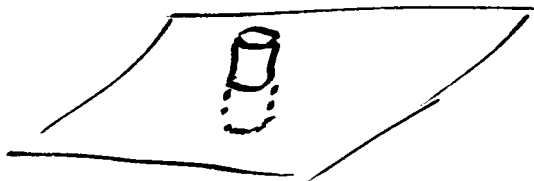
Line



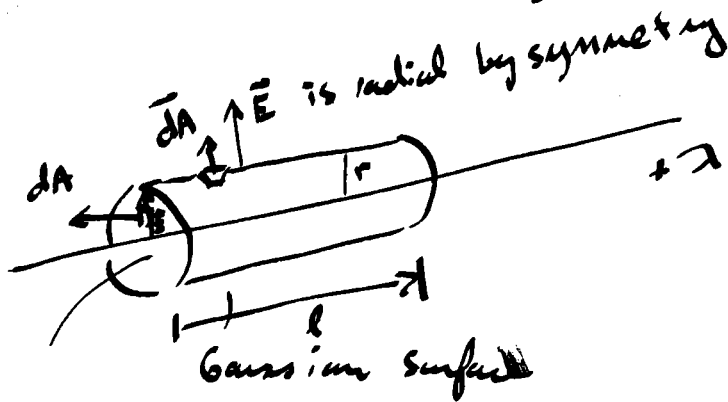
sphere



Plane



What is \vec{E} for ∞ line charge



$$\int \vec{E} \cdot d\vec{A} = \int_{\text{endcap 1}} \vec{E} \cdot d\vec{A} + \int_{\text{endcap 2}} \vec{E} \cdot d\vec{A} + \int_{\text{cylinder}} \vec{E} \cdot d\vec{A}$$

$\vec{E} \cdot d\vec{A} = 0$ \vec{E} is constant at a fixed radius
 $\vec{E} \perp$ to $d\vec{A}$

$$\int_{\text{cylinder}} \vec{E} \cdot d\vec{A} = |E| \int dA = E 2\pi r l = \frac{Q_{enc}}{\epsilon_0}$$

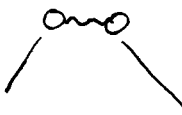
by Gauss's law

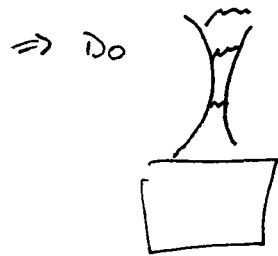
$$Q_{enc} = \lambda l$$

$$\therefore E = \frac{\lambda l}{2\pi r l \epsilon_0} = \frac{\lambda}{2\pi r \epsilon_0} \quad \text{radially outward}$$

Conductor - charges can move freely (in response to \vec{E})

insulator - charges cannot move freely
under normal circumstances

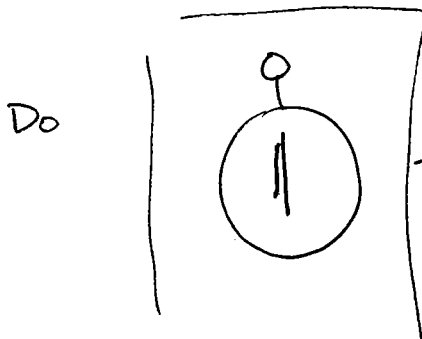
Remember:  DEMO



DEMO

insulators
can
break down

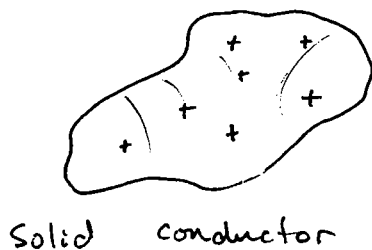
Semiconductor - "conductivity" depends on environment
(size of electric field)



Shielded Electro scope

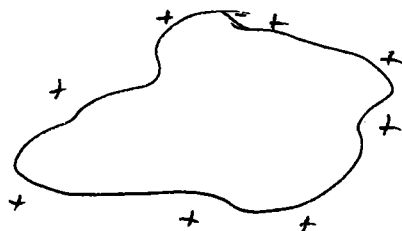
- cage DEMO

\Rightarrow Why does this happen?



Place charge instantaneously
in arbitrary spots
inside

\Rightarrow what happens



Charges rearrange until
No \vec{E} inside

if \vec{E} - charges flow
until No \vec{E}

