Electricity and Magnetism

- Physics 259 – L02
- Lecture 19

Midterm Review

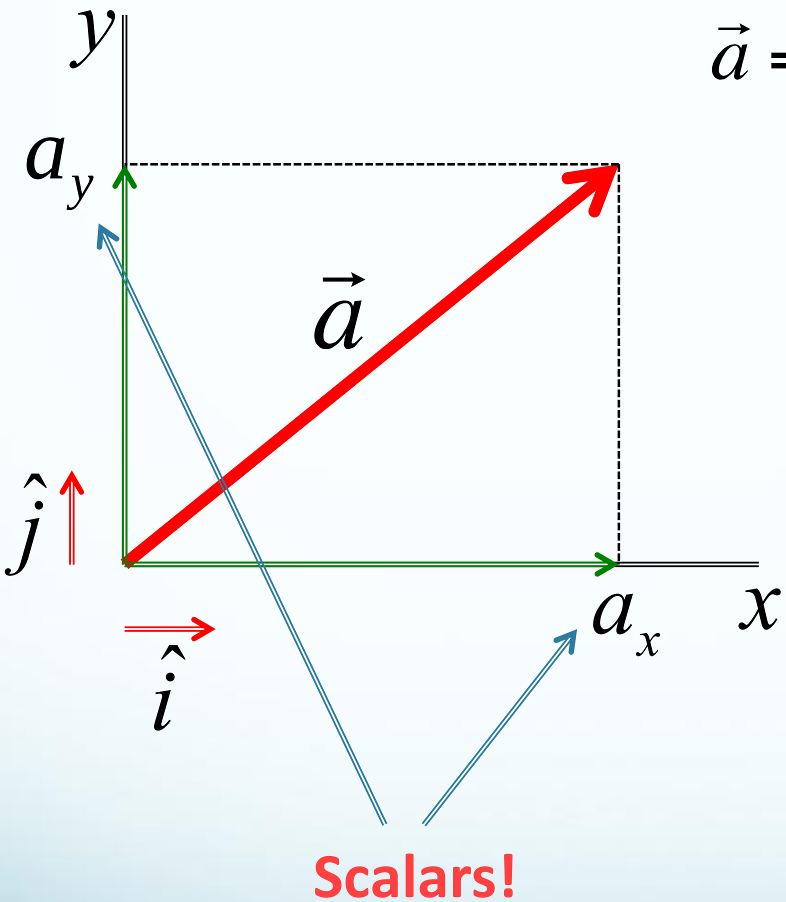
Vector Components

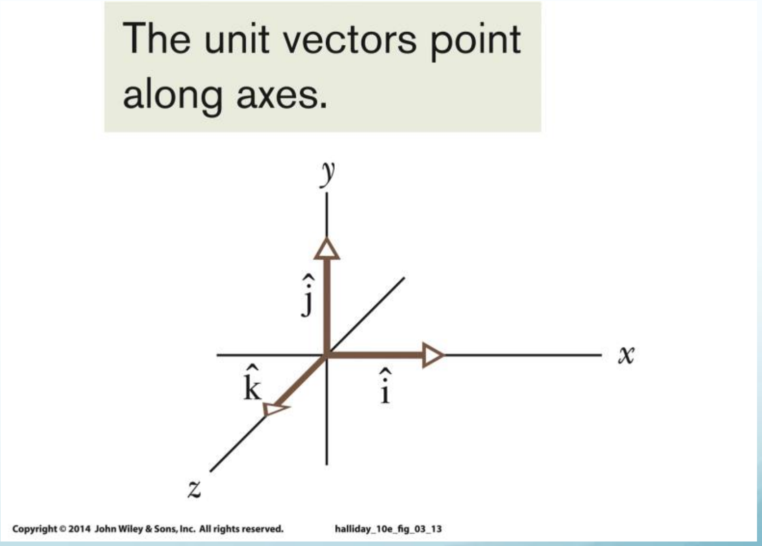
$$\vec{a} = a_x \hat{i} + a_y \hat{j}$$

$$|\vec{a}| = \sqrt{a_x^2 + a_y^2}$$

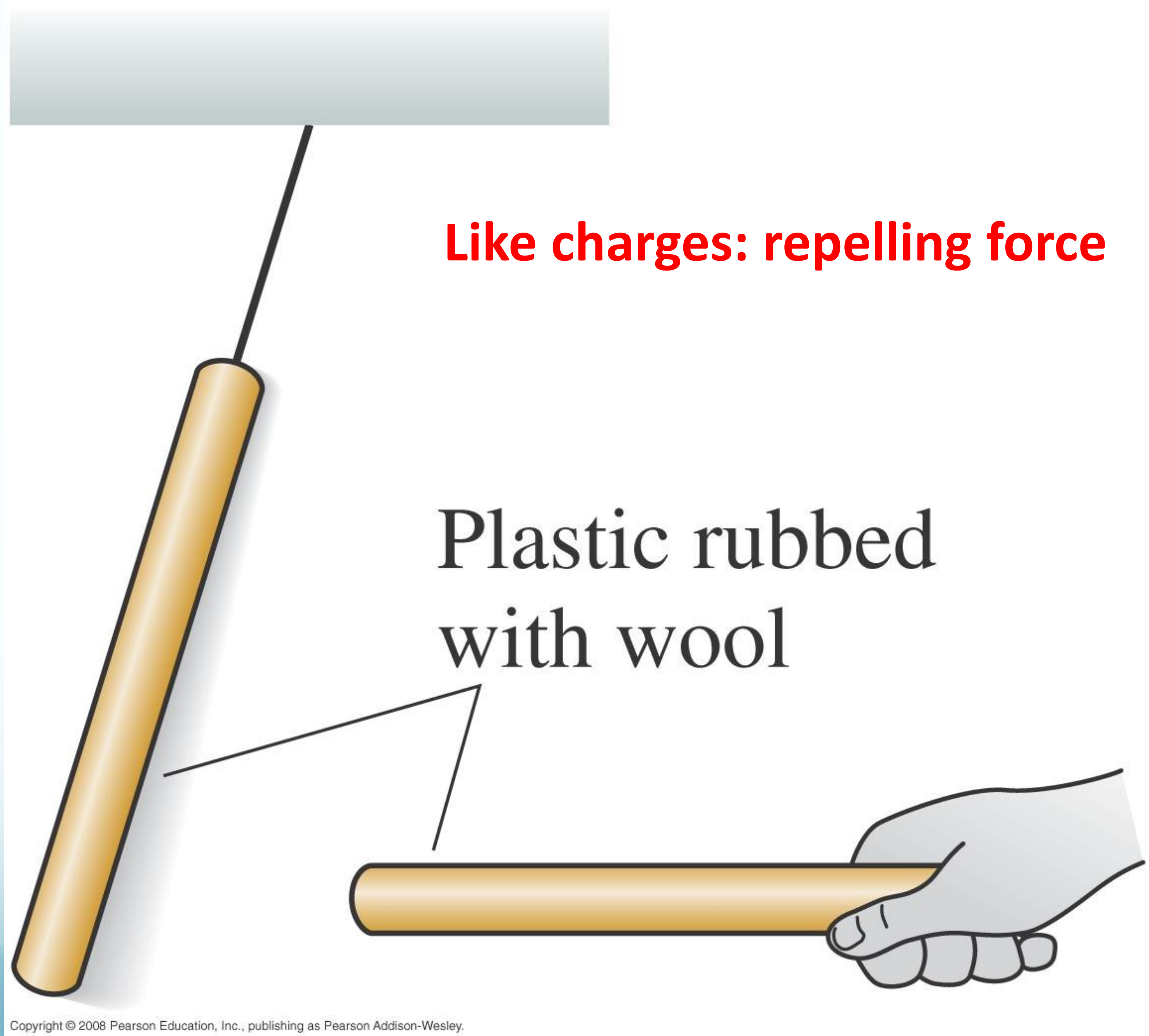
$$a_y = a \sin\theta$$

$$a_x = a \cos\theta$$

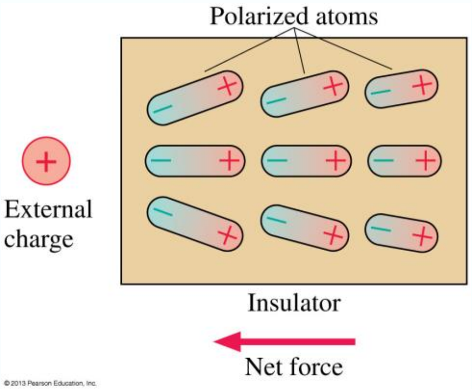


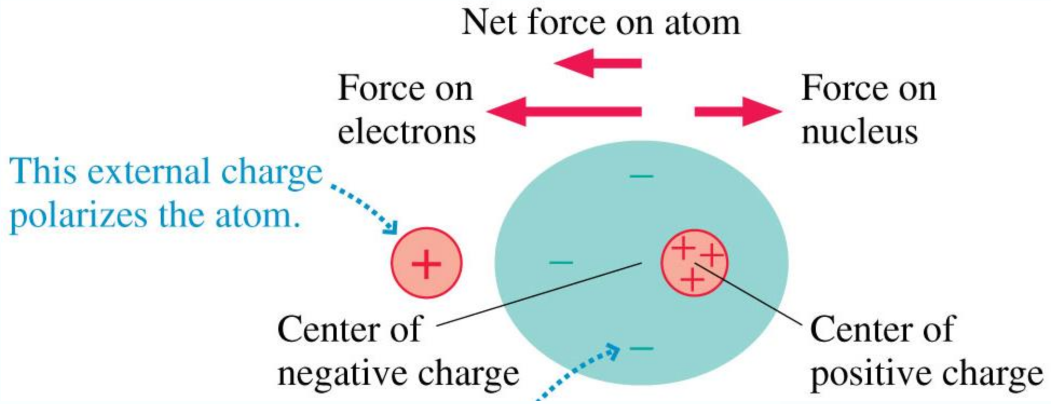


Like charges: repelling force

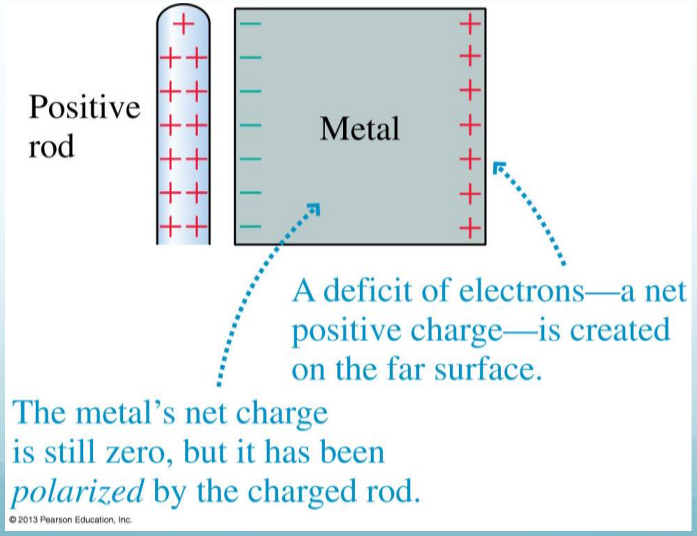


Charge Polarization





Metal

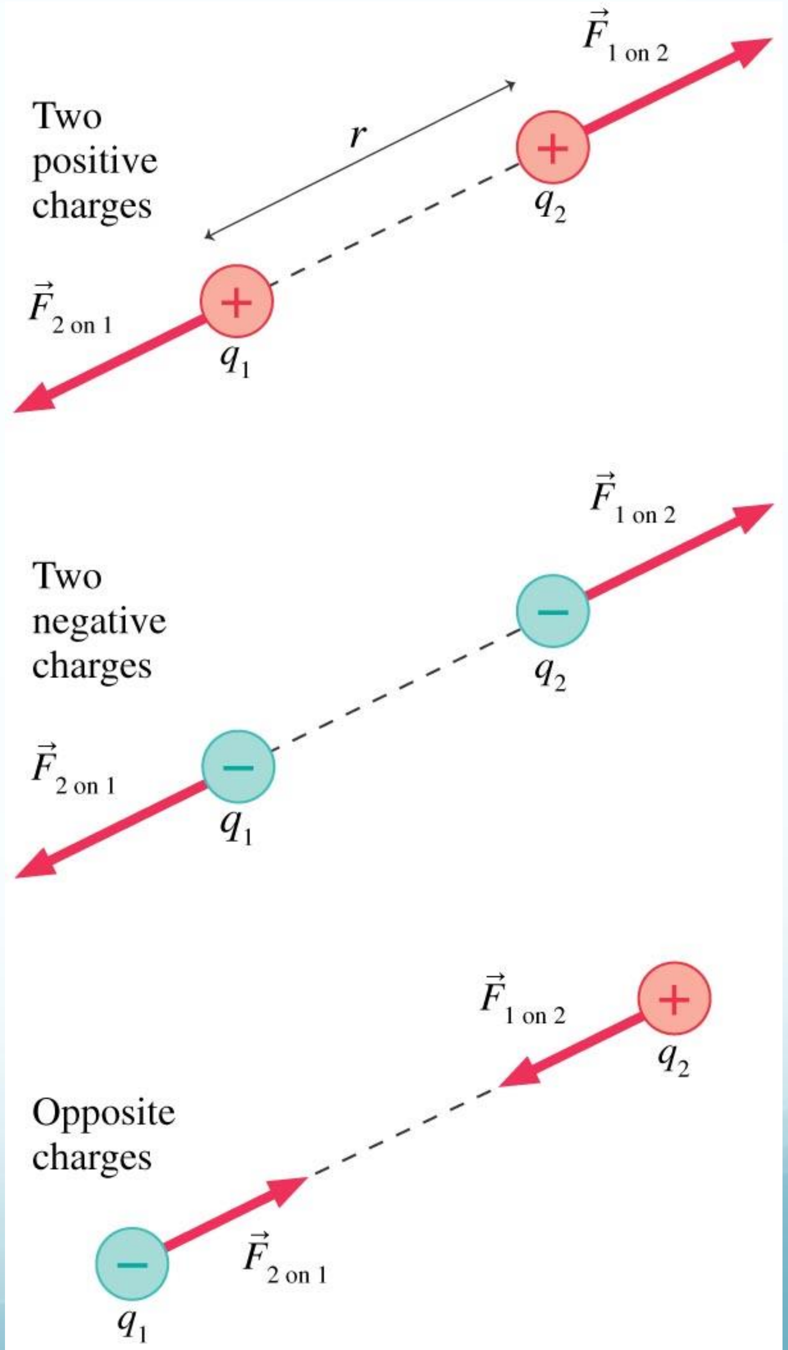


Coulomb’s Law

Describes the forces that charged **particles** exert on each other:

point charges

The forces always act along the line joining the charges.



Coulomb's Law

$$\boxed{F_{1\,on\,2} = F_{2\,on\,1} = K\frac{|q_1||q_2|}{r^2}}$$

K = electrostatic constant

$$K = 8.99 \times 10^{9}\ \frac{N \cdot m^2}{C^2}$$

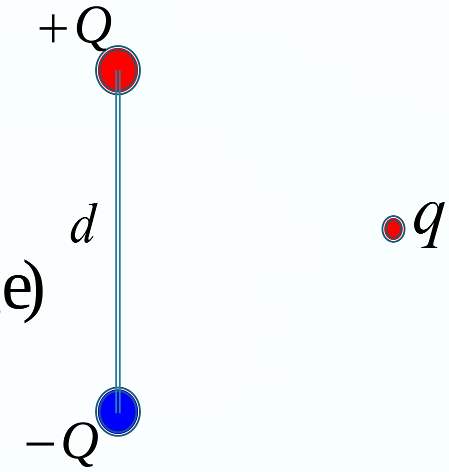
$$\boxed{F_{1\,on\,2} = F_{2\,on\,1} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}}$$

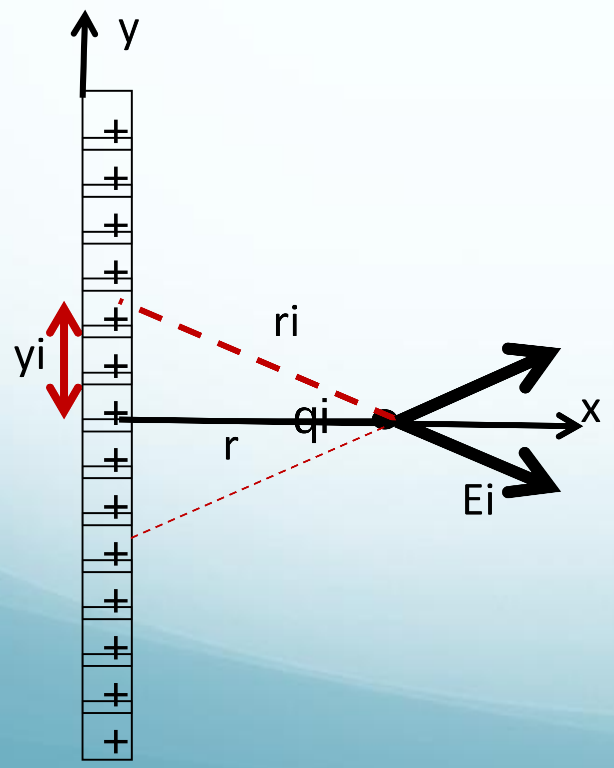
ε_0 = permittivity of free space

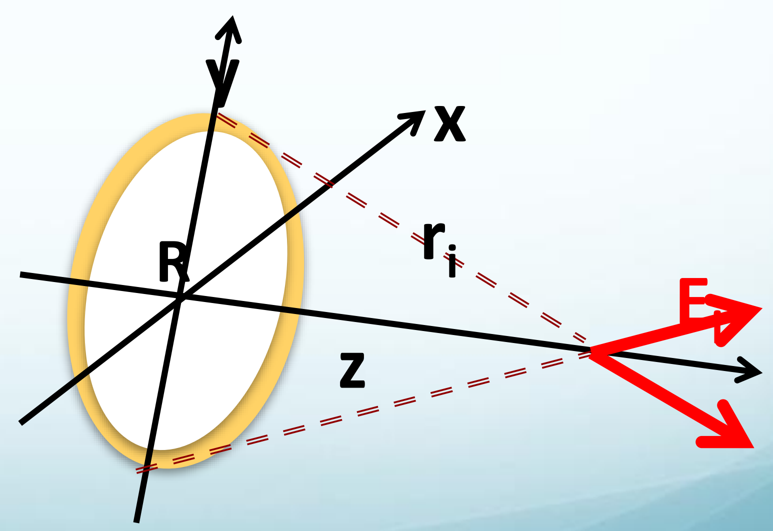
$$\varepsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{12}\ \frac{C^2}{N \cdot m^2}$$

Two point charges (Electric Dipole)

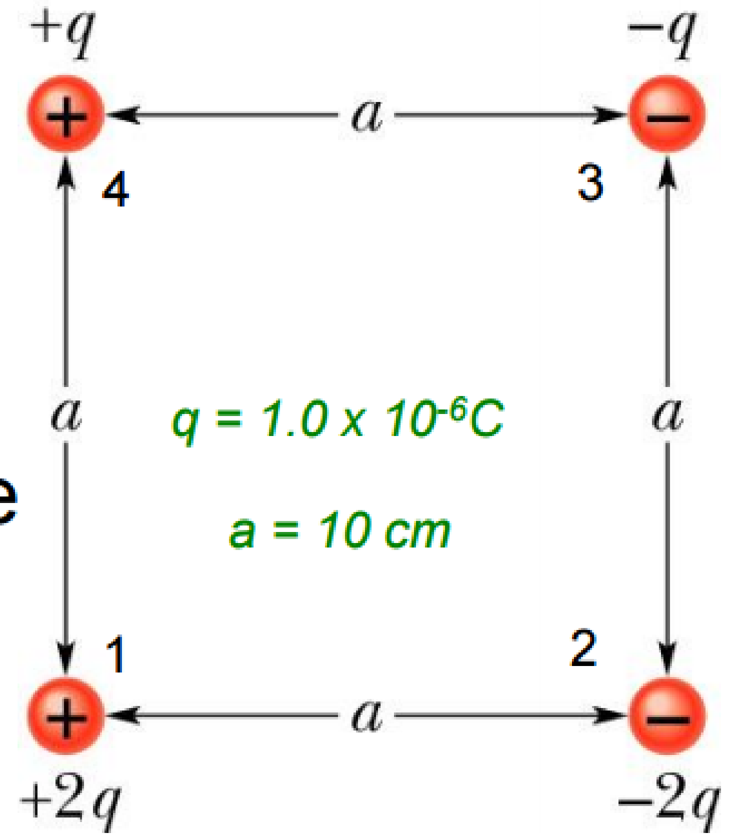
$$\vec{p} = (qs, \text{from the negative to positive charge})$$







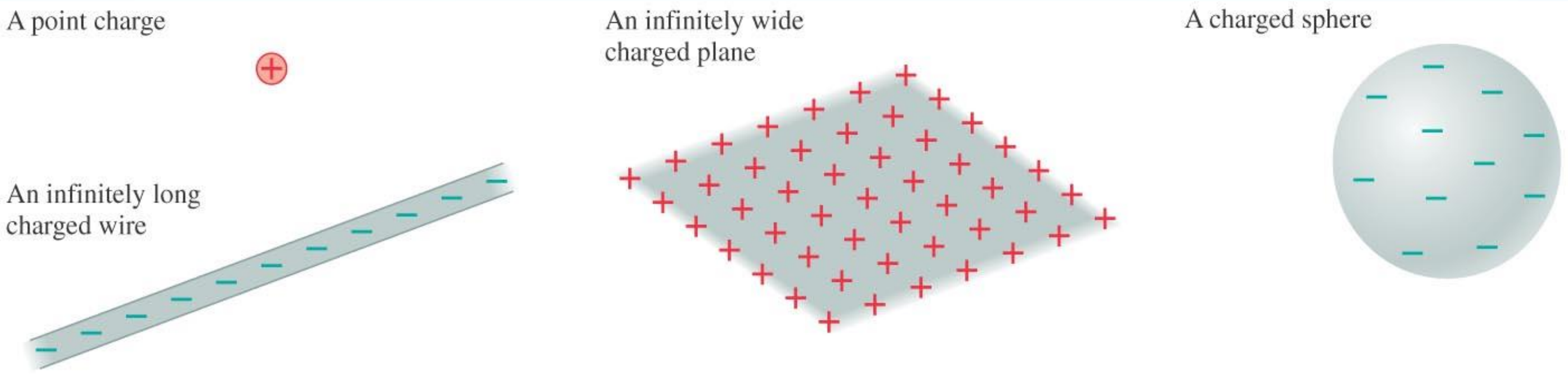
Calculate the net force on particle 1.



Use superposition principle

$$\vec{F}_{1,net} = \vec{F}_{2\ on\ 1} + \vec{F}_{3\ on\ 1} + \vec{F}_{4\ on\ 1}$$

4 basic geometries

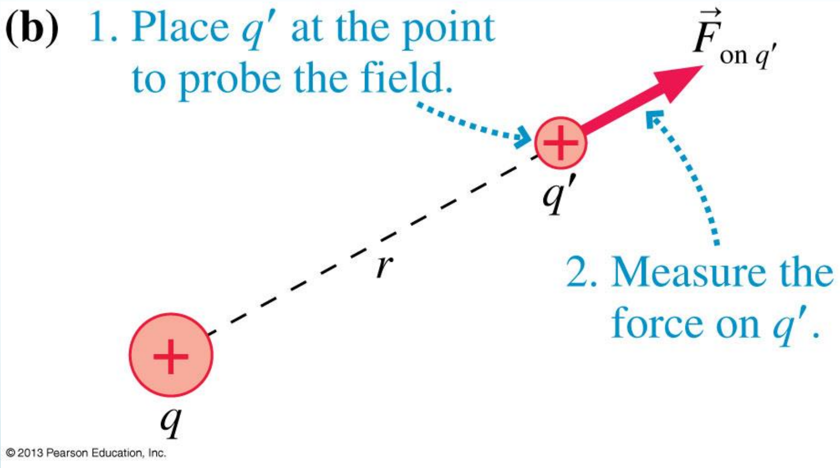


Linear, surface and volume charge densities

$$\lambda = \frac{Q}{L} \qquad \sigma = \frac{Q}{A} \qquad \rho = \frac{Q}{V}$$

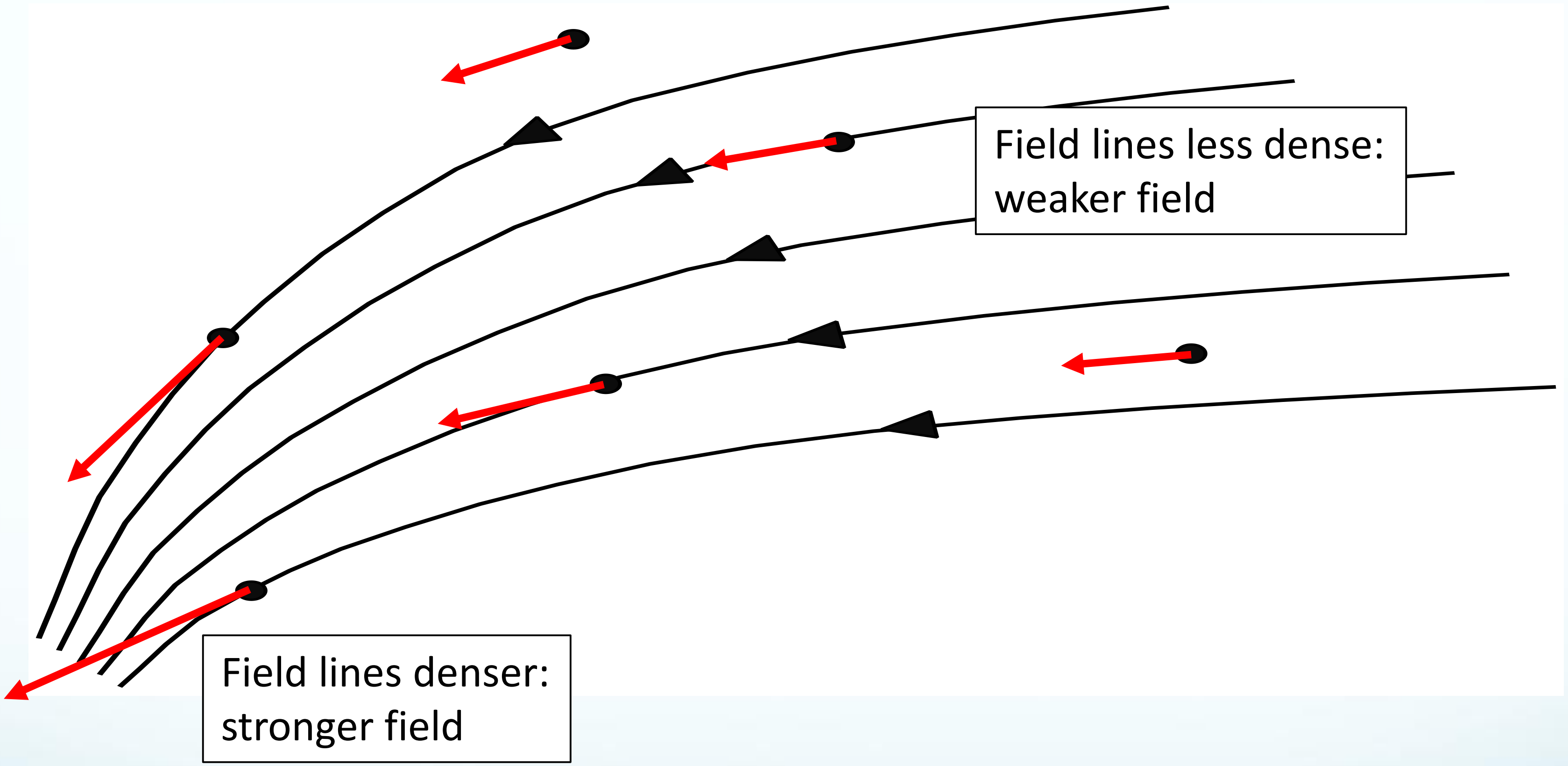
Electric fields

$$\vec{E}(x,y,z)=\frac{\vec{F}_{\text{on q}}\ \text{at}\,(x,y,z)}{q}$$



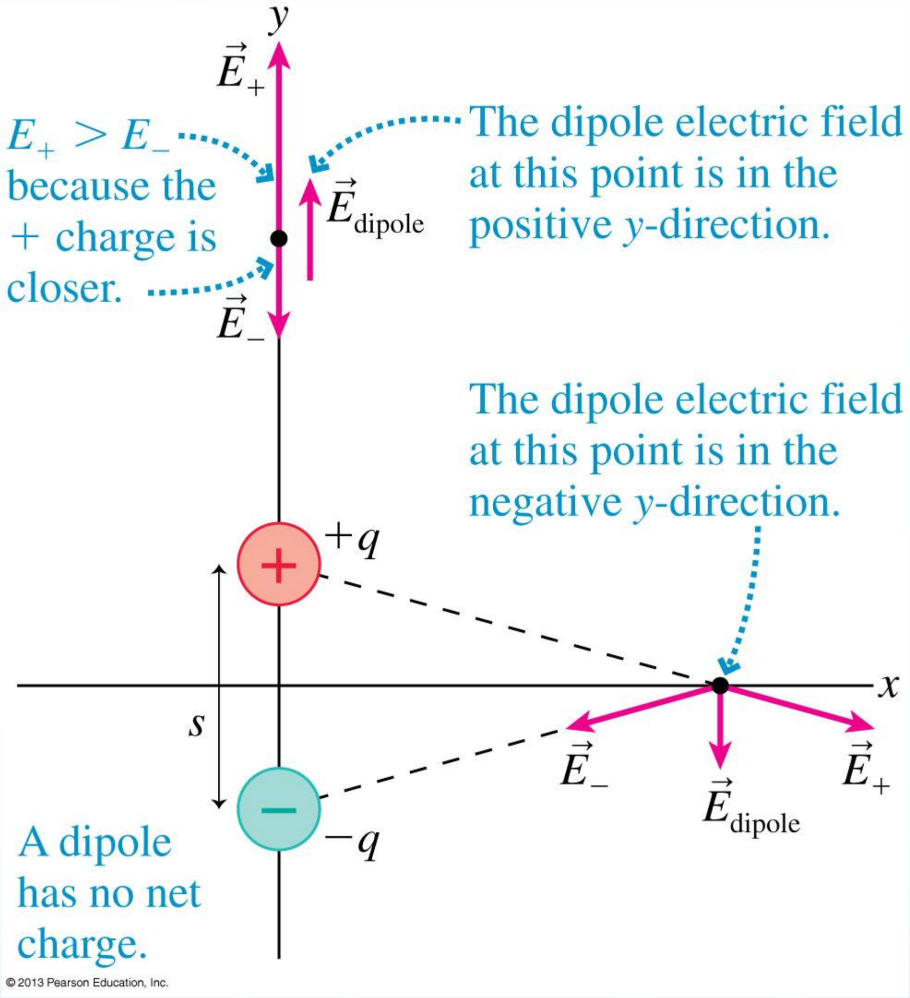
$$\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

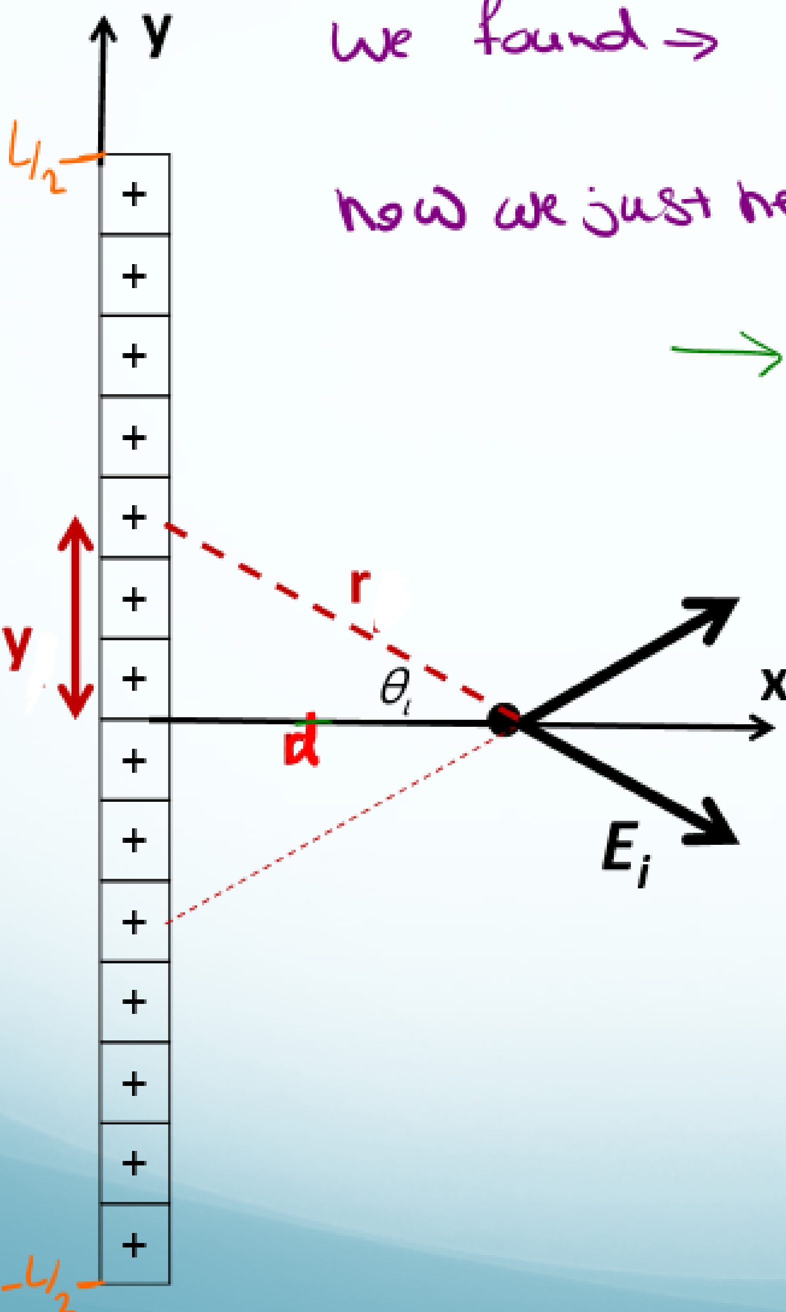
Electric Field Lines



Electric field lines are continuous curves. The electric field vectors are tangent to the field lines

The denser the field lines, the stronger the field (magnitude of E)


y
$\vec{E}_+$
$E_+ > E_-$ because the + charge is closer.
The dipole electric field at this point is in the positive y-direction.
$\vec{E}_{dipole}$
$\vec{E}_-$
The dipole electric field at this point is in the negative y-direction.
$+q$
s
x
$\vec{E}_-$
$\vec{E}_{dipole}$
$\vec{E}_+$
$-q$
A dipole has no net charge.
© 2013 Pearson Education, Inc.



we found => $F_{net,x} = \int_{-L/2}^{L/2} \frac{d\, k q \lambda\, dy}{(d^2+y^2)^{3/2}}$

now we just need to solve the integral =>

$\rightarrow \vec{F}_{net} = \frac{kQq}{d\sqrt{(L/2)^2 + d^2}}\,\hat{i}$

limiting cases =>

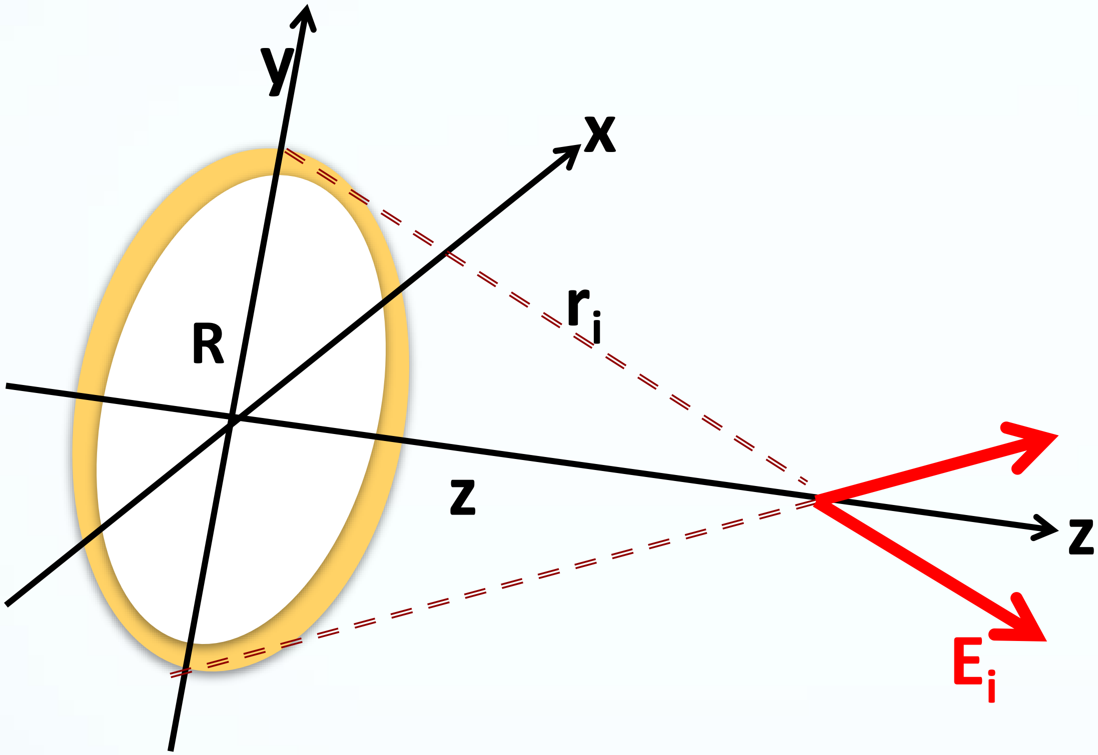
① $d \gg L \Rightarrow d^2 + \cancel{(L/2)^2} \simeq d^2$ 0

$\vec{F}_{net} = \vec{F}_{net} = k\frac{Qq}{d^2}$

② $d \ll L \Rightarrow \cancel{d^2} + (\frac{L}{2})^2 \simeq (\frac{L}{2})^2$ 0

$\vec{F}_{net} = k\frac{qQ}{L/2} = k\frac{2qQ}{L}$

infinite long wire

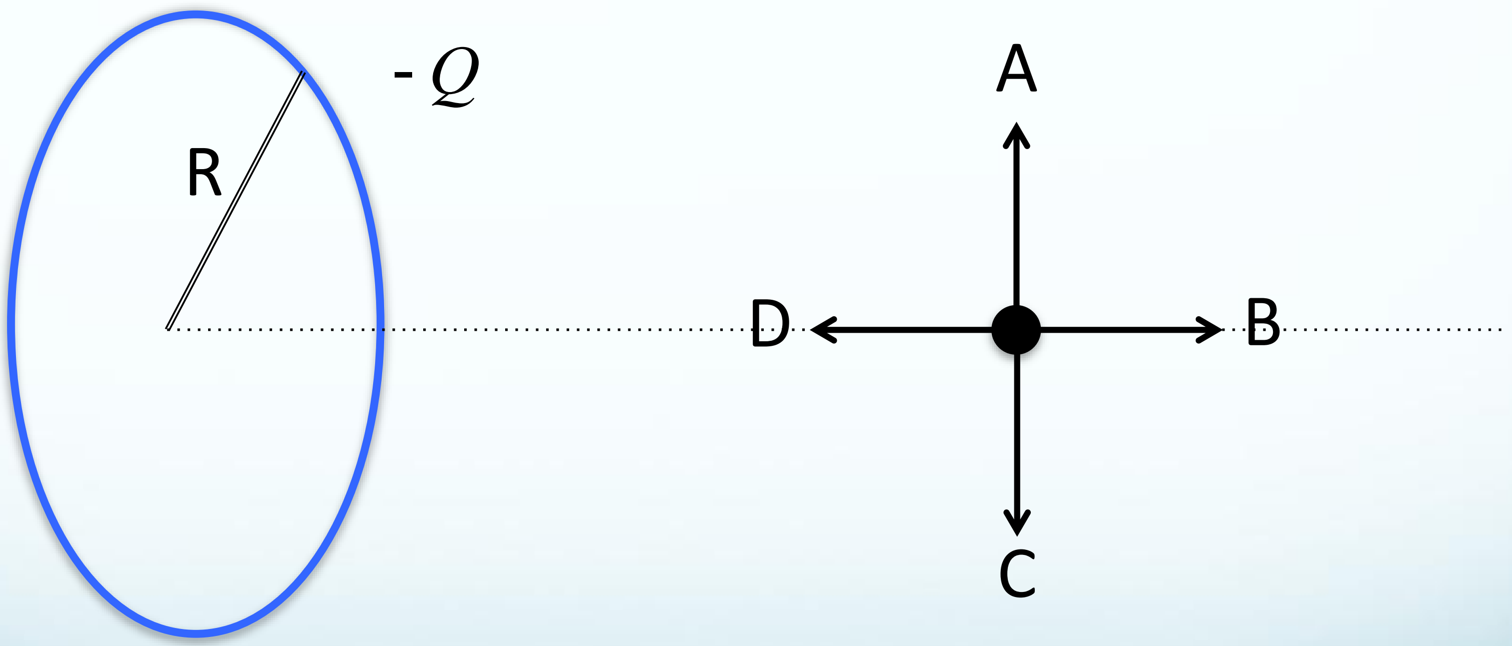


$$(E_i)_z = \frac{1}{4pe_o}\frac{zDQ}{\left(z^2+R^2\right)^{\frac{3}{2}}}$$

Z=0 → $$E_{ring} = \frac{1}{4\pi\varepsilon_o}\frac{zQ}{\left(z^2+R^2\right)^{3/2}}$$ **→ E=0**

Z>>R → $$E_{ring} = \frac{1}{4pe_o}\frac{zQ}{\left(z^2+0^2\right)^{3/2}} = \frac{1}{4pe_o}\frac{Q}{z^2}$$

What is the direction of the electric field at the point indicated?



A disk of charge

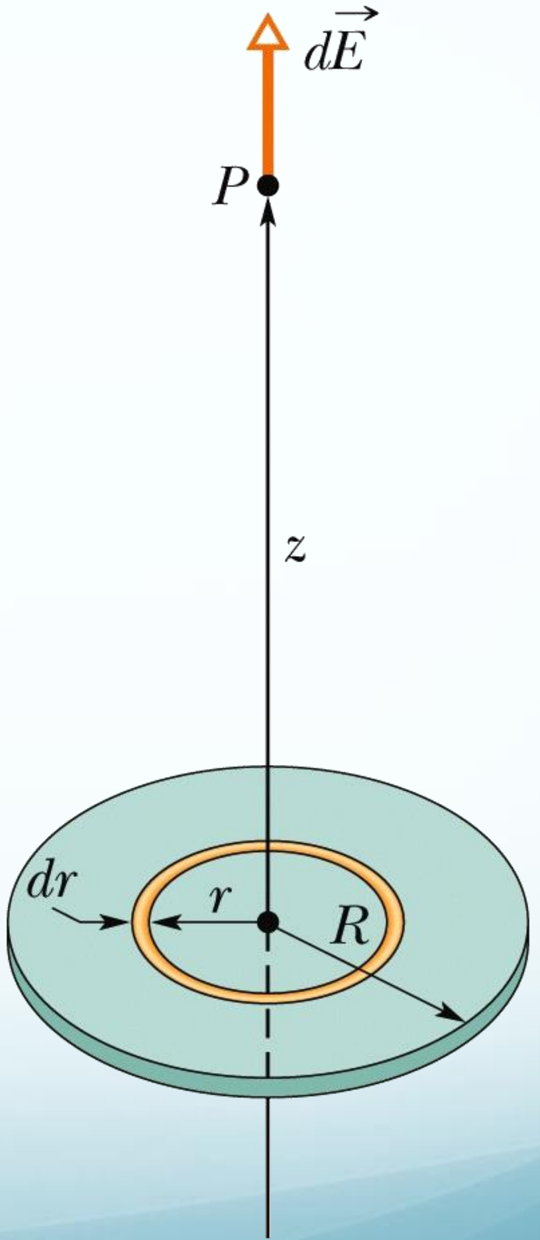
$$E_{disk,z} = \frac{\sigma}{2\varepsilon_o}\left[1 - \frac{z}{\sqrt{z^2 + R^2}}\right]$$

Z>>R

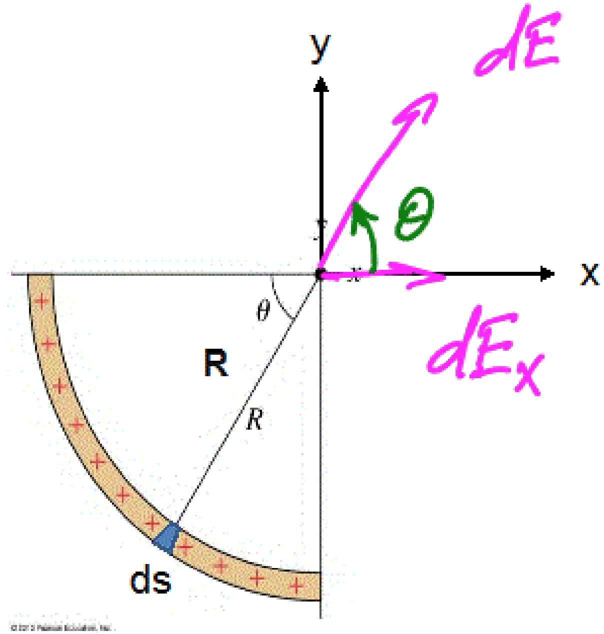
$$E_{disk,z} = \frac{Q}{4\pi\varepsilon_o z^2}$$

Z→0

$$E_{disk,z} = \frac{\sigma}{2\varepsilon_o}$$



P16) A non-conducting plastic rod has been bent into the quarter-circle shape shown below. Electrons have been removed, and the linear charge density λ, in C/m, is uniform.



a) To the best of your artistic abilities, redraw this figure in your answer sheet, and draw an arrow representing the electric field at the origin <u>due only</u> to the charge in the segment ds. Call this electric field vector **dE**.

b) Write an expression for the amount of charge, dq, contained in the small segment ds.

$$dq = \lambda\, ds$$

c) Write an expression for the magnitude of the electric field at the origin, dE, due to the small amount of charge dq.

$$dE = \frac{1}{4\pi\epsilon_0}\frac{dq}{R^2}$$

The Electric Flux

Amount of electric field going through a surface

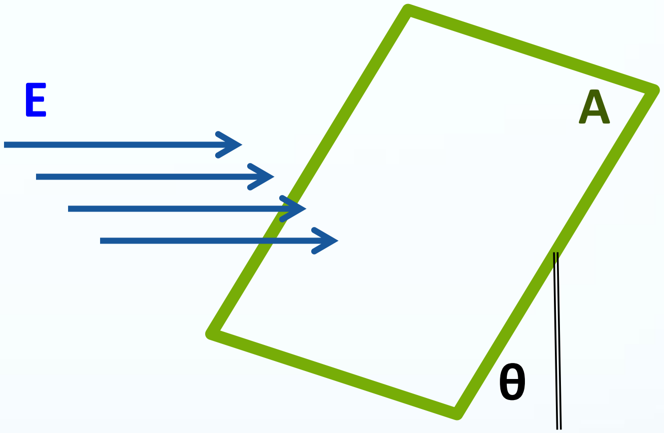
$\Phi_e \; \alpha \; E$

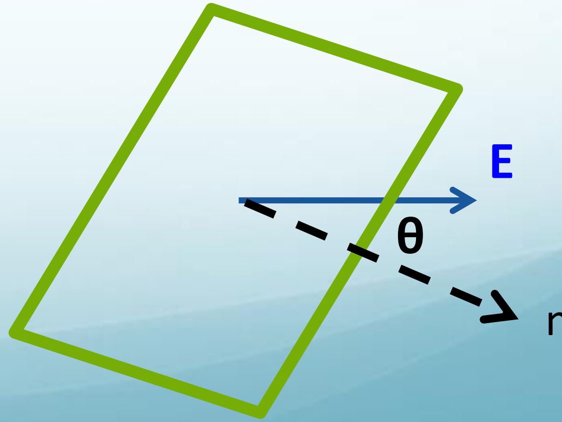
$\Phi_e \; \alpha \; A$

$\Phi_e \; \alpha \; \theta$

$$\boxed{\Phi_e = E_{\perp} A = EA\cos\theta}$$

$$\rightarrow \Phi_e = E.A$$





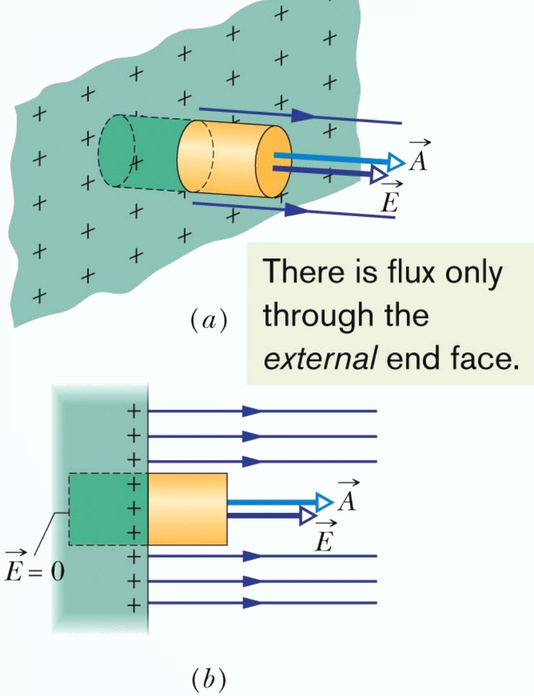
Gauss' law relates the net flux ϕ of an electric field through a closed surface (a Gaussian surface) to the *net* charge q_{enc} that is enclosed by that surface.

$$\varepsilon_0 \Phi = q_{\text{enc}} \qquad \text{(Gauss' law).}$$

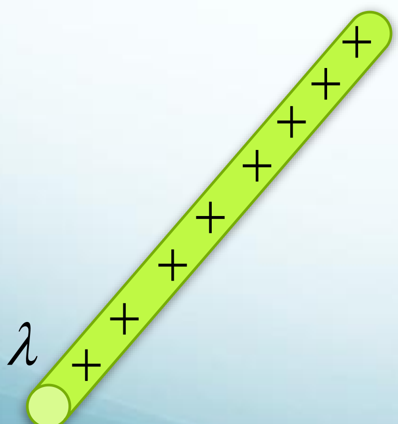
we can also write Gauss' law as

$$\varepsilon_0 \oint \vec{E} \cdot d\vec{A} = q_{\text{enc}} \qquad \text{(Gauss' law).}$$

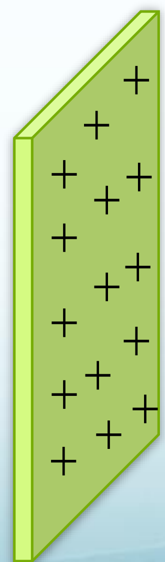
Gauss's law applies to closed surfaces



$$E = \frac{\sigma}{\varepsilon_0} \quad \text{(conducting surface).}$$

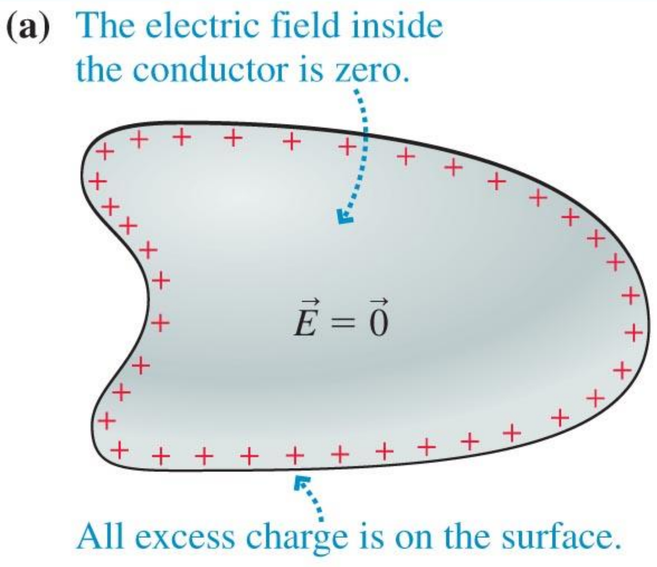


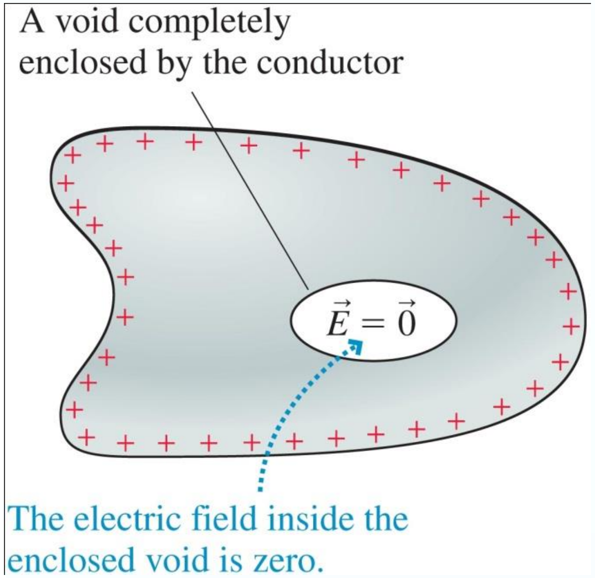
$$E_{wire} = \frac{\lambda}{2\pi\varepsilon_0 r}$$

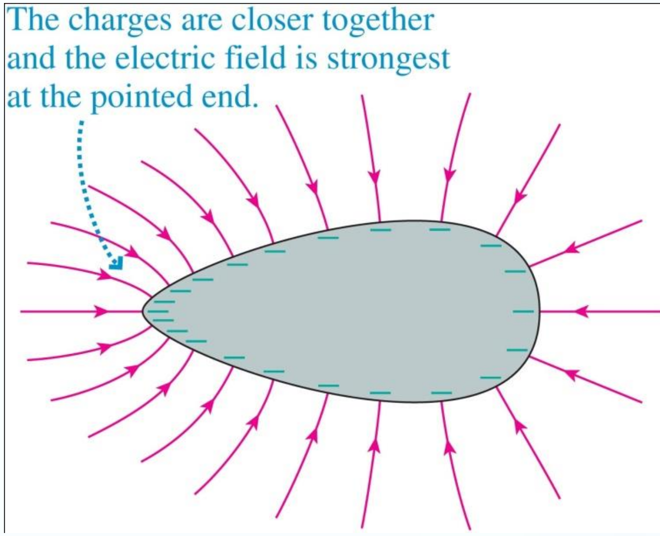


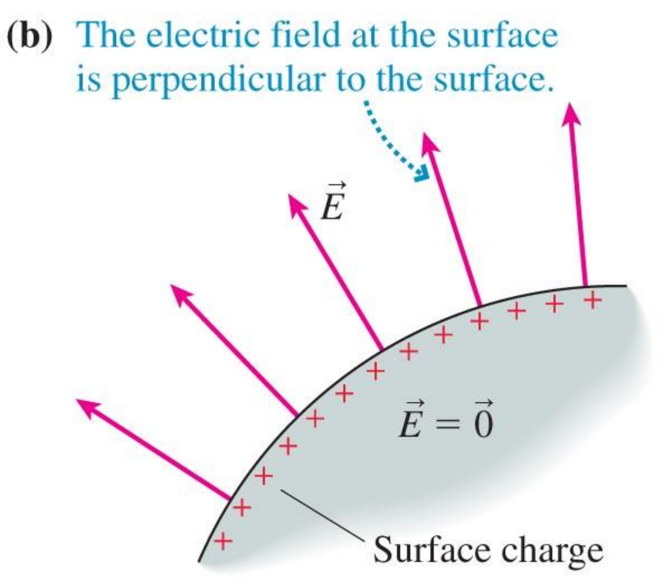
$$E_{plane} = \frac{\sigma}{2\varepsilon_0}$$

Summary of Conductors and Electric Fields

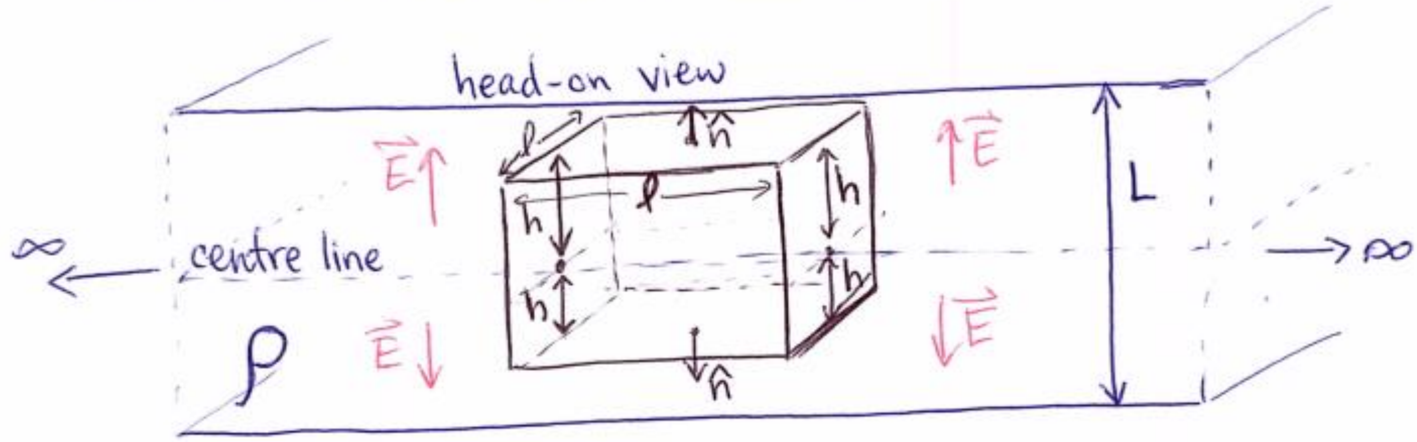


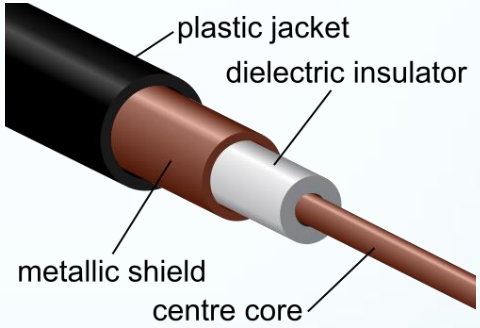


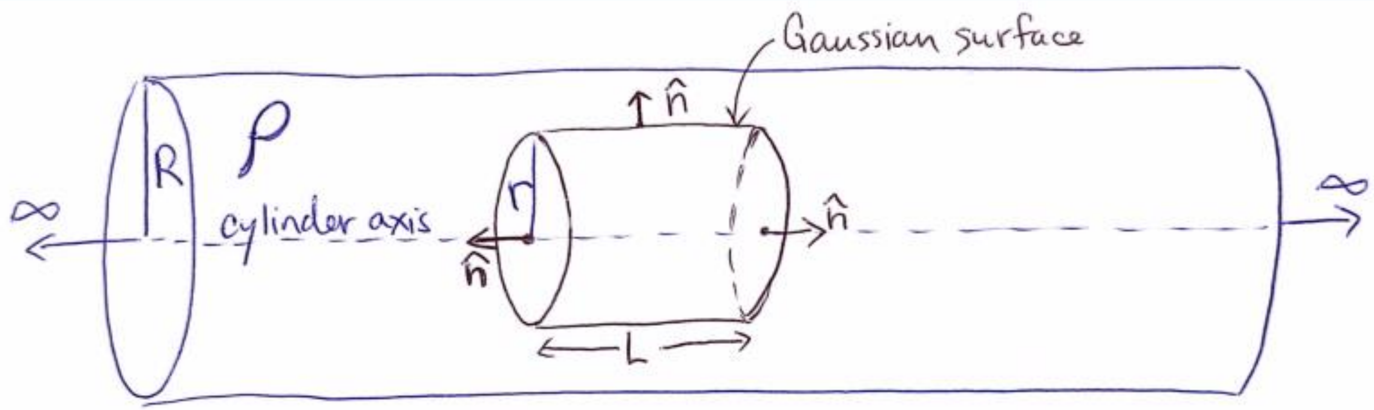




What is the field inside the slab?

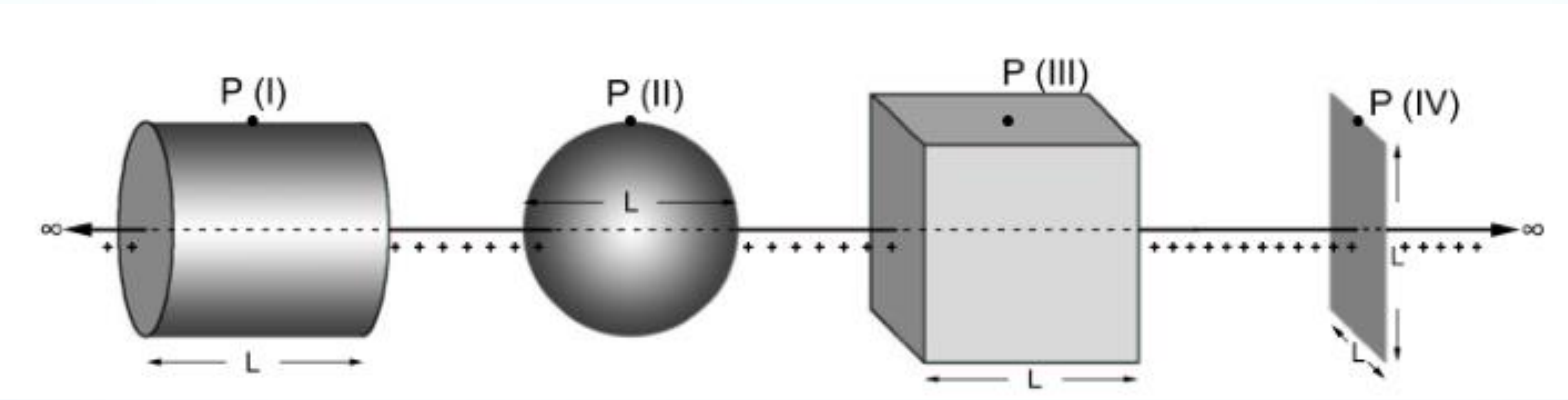






TopHat Question

4 surfaces are coaxial with an infinitely long line of charge with a uniform linear charge density = λ. Choose all the surfaces through which $\Phi_E = \lambda L / \varepsilon_0$



A) I only

B) I and II only

C) I and III only

D) I, II, and III only

E) All four.

This section we talked about:

Midterm Review

See you Tomorrow