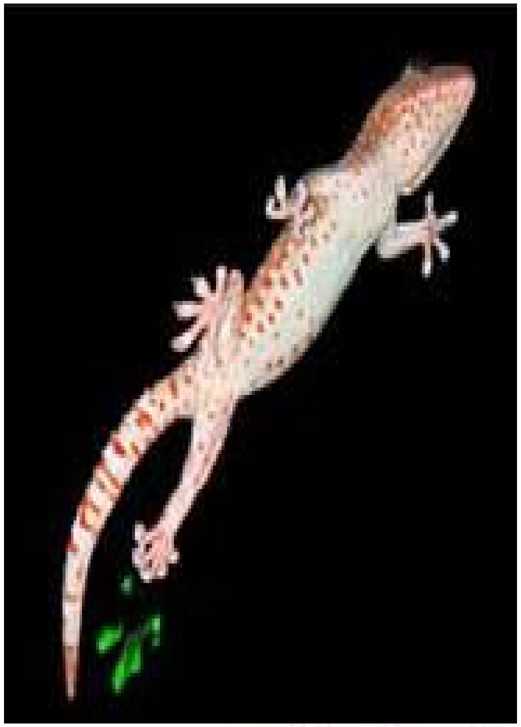
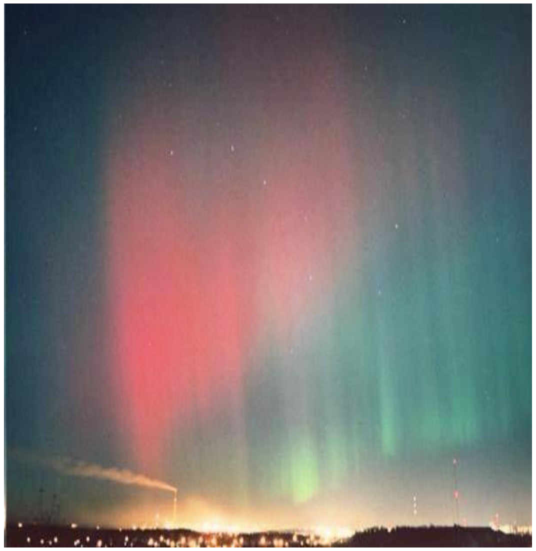


Physics 151



Electric Charge

Coulomb's Law of Force

Electric Fields

Gauss's Law

Electric Potenial

Capicitance

Electric Current

Conductors

DC Electric Circuits

Magnetic Fields

Biot-Savart Law and Ampere's Law

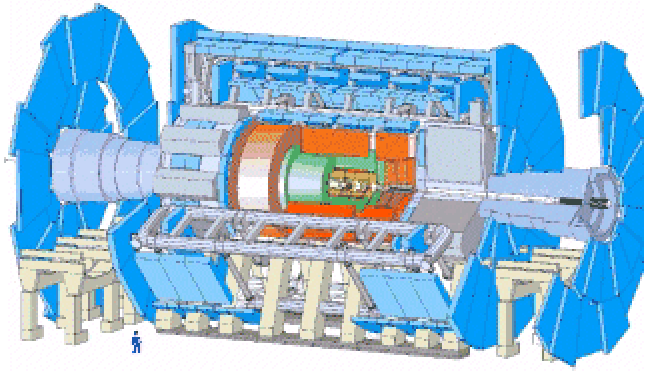
Inductance and Faraday's Law

Electromagnetic Waves

Propagation

Interference

Diffraction



Electric Charge

- **Experimental findings**
  - **Exists in two forms: called positive (+) and negative (-) by Benjamin Franklin in 1700's**
    - **Like charges repel**
    - **Unlike charges attract**
  - **Charge is conserved in a closed system**
  - **Charge is quantized**
    - **Natural unit is charge on electron |e| = 1.60x10-19 Coulomb (C)**
    - **First constituent of atom to be isolated in 1897 by J.J. Thomson**
      - **Electron charge is negative = -e**
      - **Proton charge is positive = +e**
- **Note – both conductors and insulators can be charged**
  - **Conductor**
    - **charge is free to move throughout this material**
  - **Insulator**
    - **charge is "locked in place" in this material**

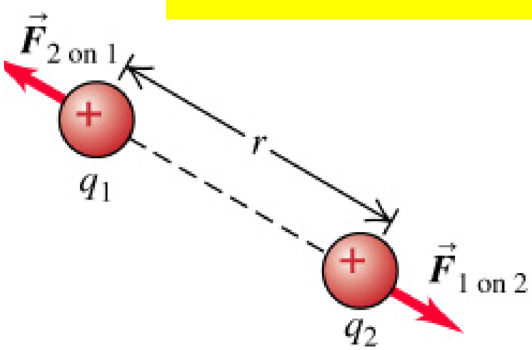
Coulomb's Law of Force

- Describes electric force, F, between two point charges, q_1 and q_2, separated by a distance, r_{12}, in a vacuum
- Experimental findings
  - Magnitude of force is proportional to the product of the charges and inversely proportional to the square of the separation
  - Direction of forces the two charges exert on each other is always along the line joining them
  - Forces are equal in magnitude and opposite in direction

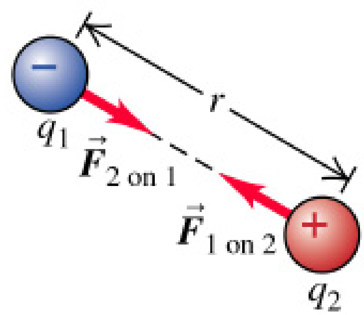
$$\left|\vec{F}_{1\,on\,2}\right| = k\frac{|q_1||q_2|}{r_{12}^2} = \left|\vec{F}_{2\,on\,1}\right|$$

<u>Units</u>

F in Newtons (N)
q in Coulombs (C)
r in Meters (m)
$k = 9\times10^9\ Nm^2C^{-2}$
$= 1/(4\pi\varepsilon_0) = 10^{-7}c^2$



(b)



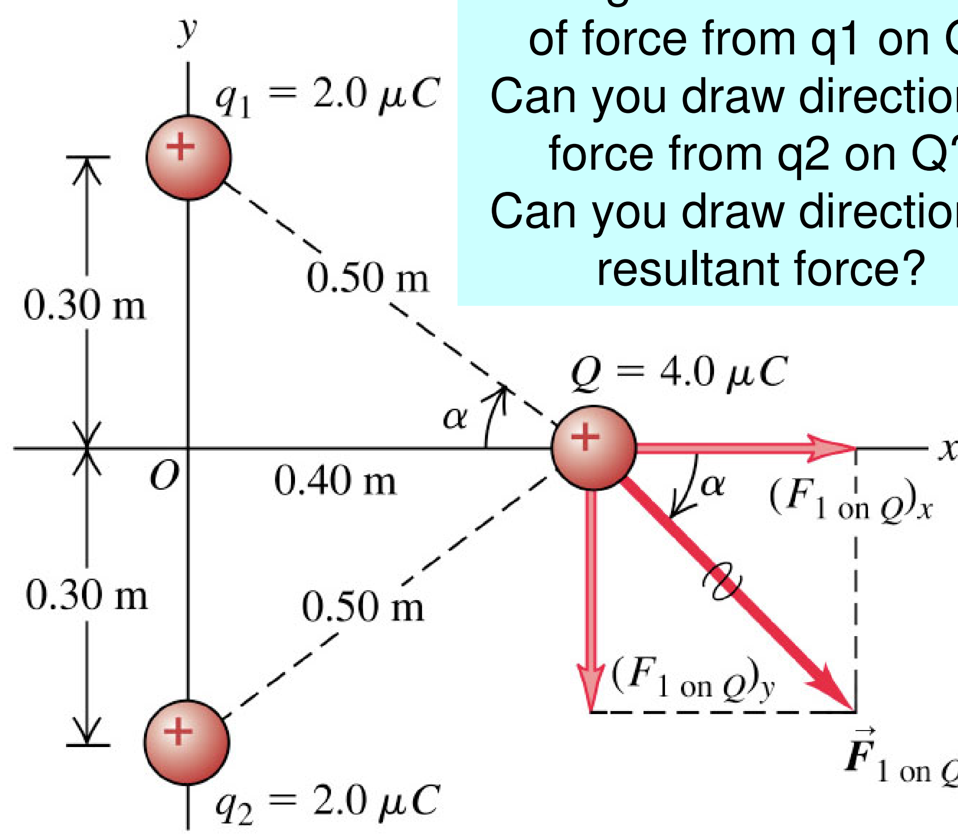
(c)

Always remember to convert units!
$cm = 10^{-2}$ m
$\mu C = 10^{-6}$ C
$nC = 10^{-9}$ C

Principle of Superposition

- What happens when there are more than two charges present?
- Experiments show that the force on any charge is the vector sum of the Coulomb forces from each of the other charges
  - This is called the principle of superposition.

- Now you can do any electrostatics problem where you know the location of all the charges!
- Read 21.1-21.3
- Do homework exercises from section 21.3



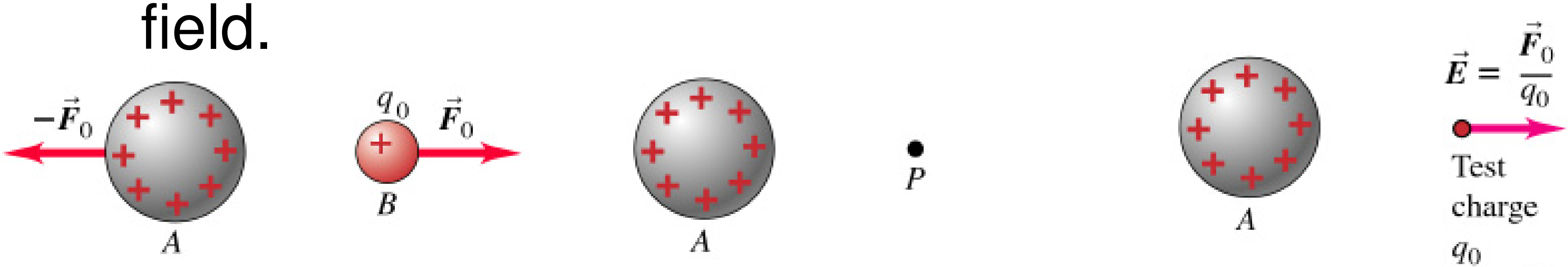
This figure shows direction of force from q1 on Q.
Can you draw direction of force from q2 on Q?
Can you draw direction of resultant force?

Do you understand…

- Polarization
  - How does a comb, charged by brushing your hair, pick up uncharged pieces of paper? Do you think the sign of the comb's charge matters?
- Induction
  - Why was the coke can attracted to both positive and negative rods?
  - What happens to the leaves of an uncharged electroscope when a positive rod is held near by?
- Draw force vectors on each charge with length proportional to the size of the force.

Electric Field

- A charge modifies the properties of the space around it. This modification is called the electric field.



(a) How does charged body A exert a force on charged body B?

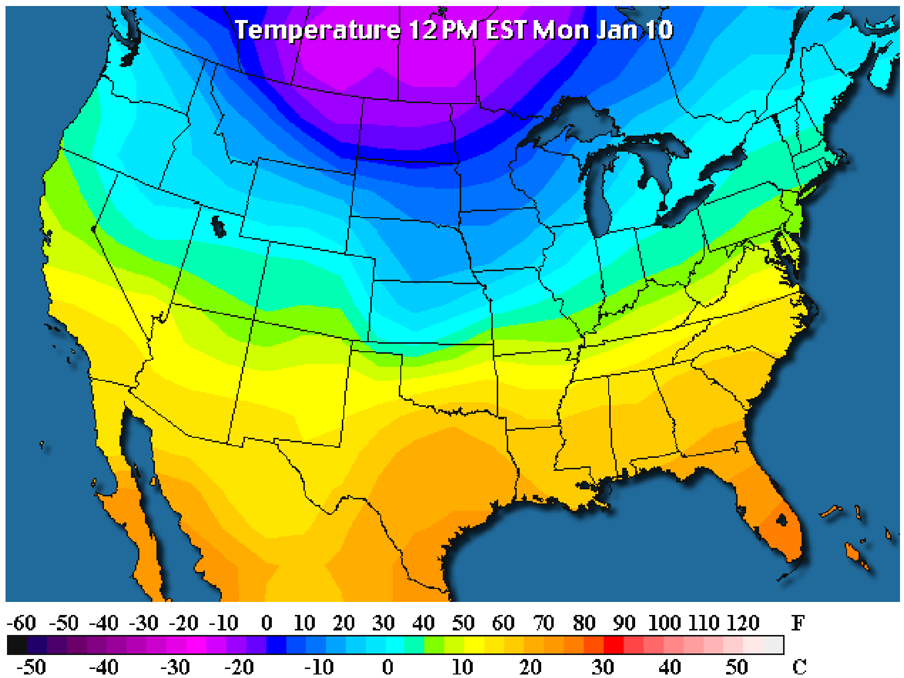
(b) Remove body B and label its former position as P

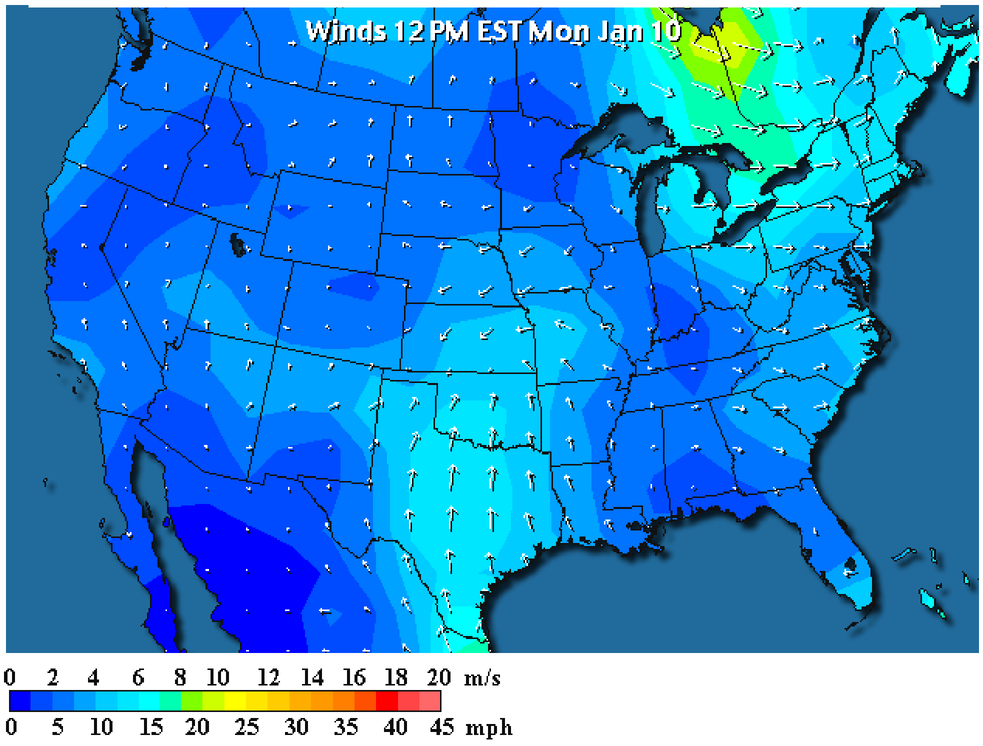
(c) Body A sets up an electric field $\vec{E}$ at point P: $\vec{E}$ is the force per unit charge exerted by A on a test charge at P

- The electric field exists at all points in space around the charge.
- The electric field at each point is a vector because it causes a test charge to experience a force in a particular direction.

What are some other fields?

- Temperature is a scalar field – it has a magnitude at each point in space but no associated direction
- Wind speed is a vector field – it has a magnitude and a direction.





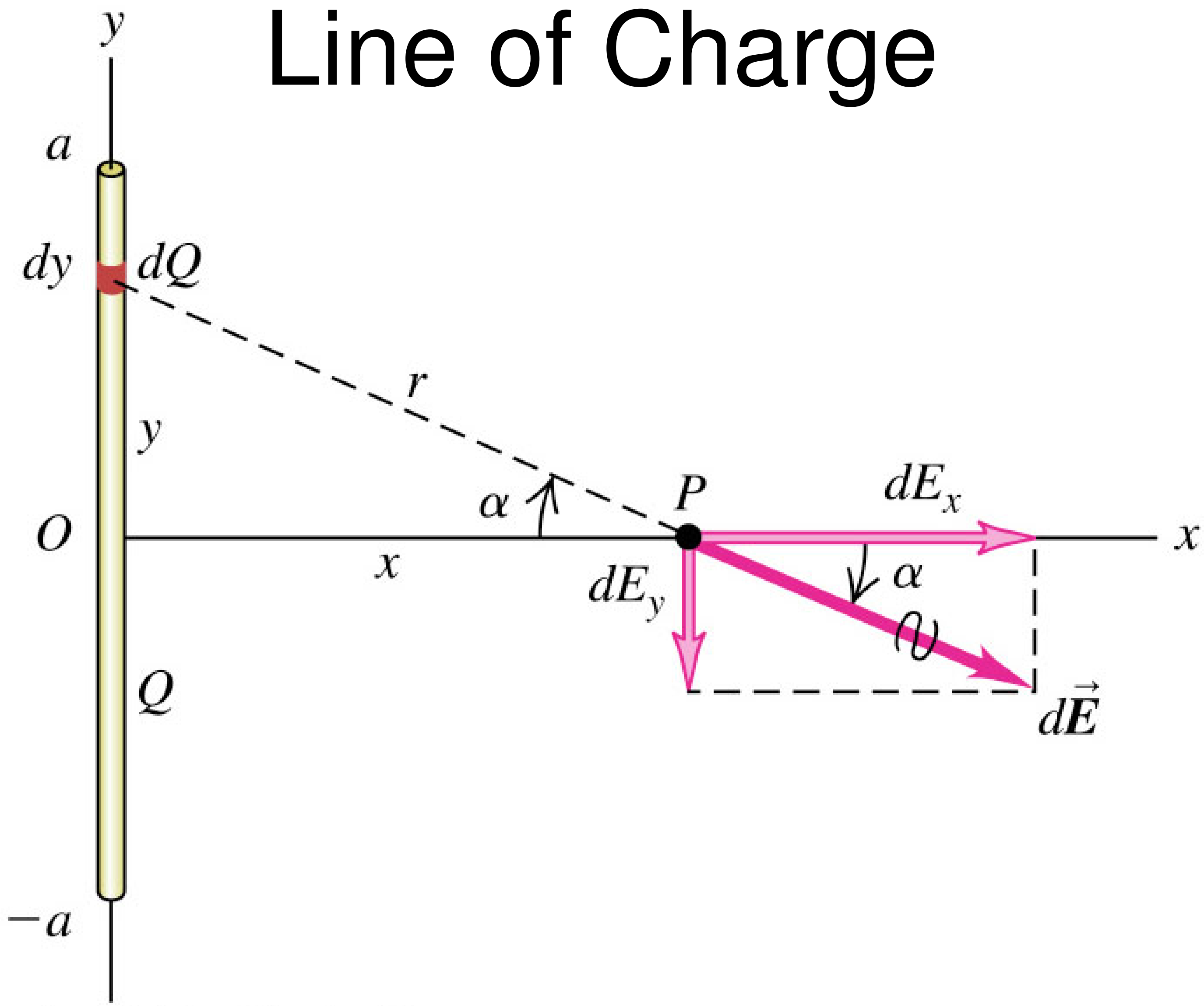
Electric Field Calculations

- Learning Objectives
  - To use the principle of superposition to calculate the electric field of multiple point charges and of continuous distributions of charge
  - To learn the electric fields of common charge distributions
    - Dipole
    - Point charge
    - Line of charge
    - Ring of charge
    - Sheet of charge
    - Two oppositely charged sheets
  - To study the motion of charged particles and dipoles in simple electric fields

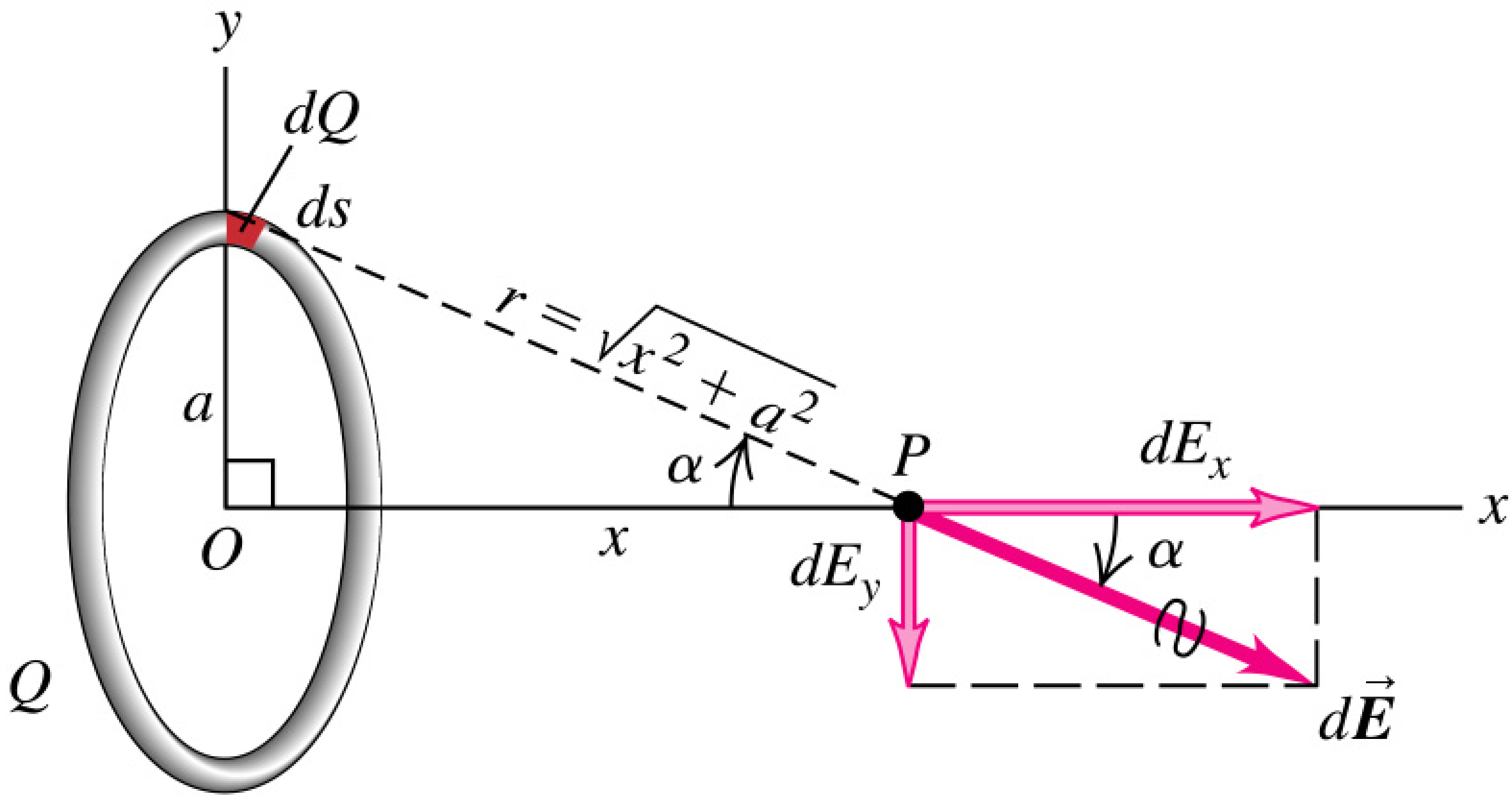
Electric Field Calculations: How to tackle them!

- Draw a picture
- Choose an element of charge dQ where you can write down the electric field dE
  - Usually choose a point charge
- Any symmetries?
- Replace dQ with an equivalent expression involving a charge density and a small geometric quantity that describes the shape of charge element dQ
- Choose coordinate to use for integration variable
  - All angles and distances must be expressed in terms of the integration variable
- Look at limiting cases – does your answer make sense?

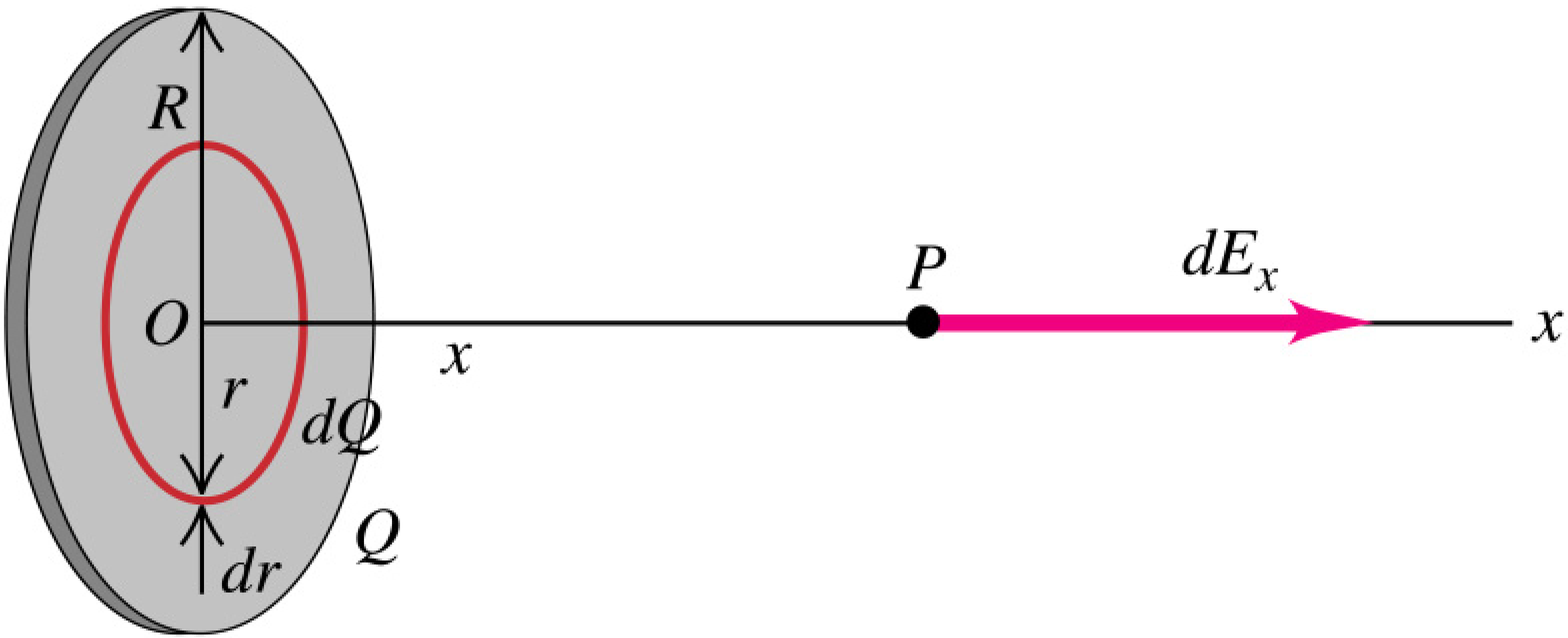
Line of Charge



Ring of Charge



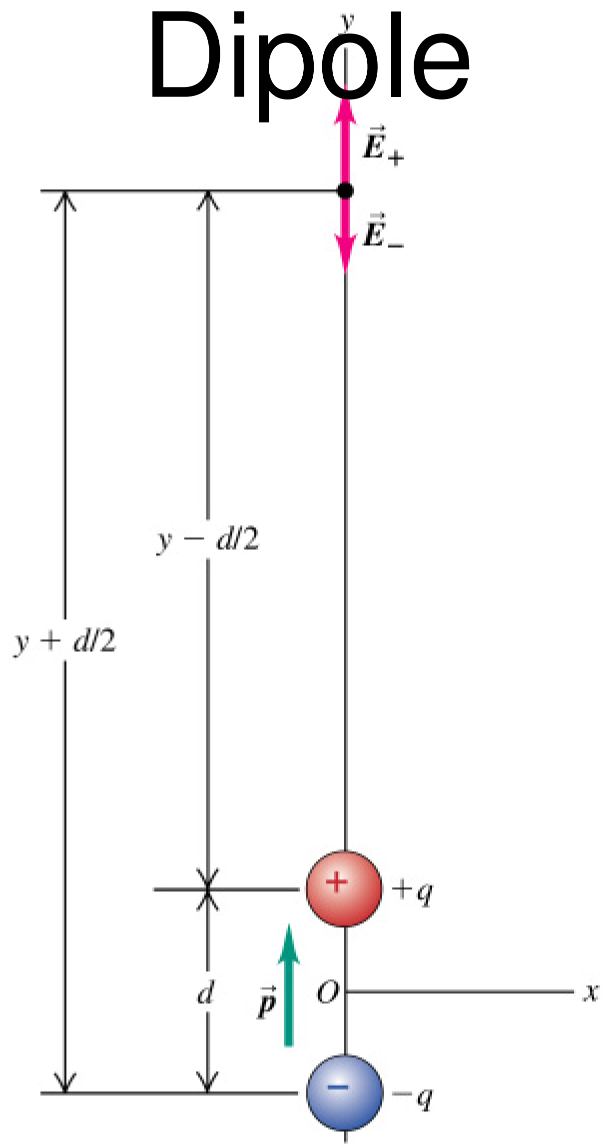
Disk of Charge



Problem 21.96

- A small sphere with mass m carries a positive charge q and is attached to one end of a silk fiber of length L. The other end of the silk fiber is attached to a large vertical insulating sheet that has a positive surface charge density σ. When the sphere is in equilibrium, what is the angle the fiber makes with the sheet?

Dipole



Summary

Configuration	E(r)	E(r)
Dipole	$\frac{1}{r^3}$	$\frac{qd}{2\pi\varepsilon_0}\frac{1}{r^3}$
Point	$\frac{1}{r^2}$	$\frac{q}{4\pi\varepsilon_0}\frac{1}{r^2}$
Infinite line	$\frac{1}{r}$	$\frac{\lambda}{2\pi\varepsilon_0}\frac{1}{r}$
Infinite sheet	constant	$\frac{\sigma}{2\varepsilon_0}$

We've covered everything in chapter 21 except for 21.6
On Friday, we will move onto chapter 22 and
learn about electric fields, electric flux and Gauss's Law