

# Course Updates

<http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html>

## Reminders:

- 1) Updates posted on web
- 2) Online HW (**Monday**), written problems  
**Wednesday**
- 3) Written problems: 21.57, 21.74
- 4) Chapter 21 this week, Chapter 22 next  
(**all this information on web page**)

# Coulomb Man - Hall of Fame or Shame?



100kg



$$F = 1000\text{N} = qE$$

$$q = 30\text{mC}$$

$$E = F/q \sim 33,000 \text{ [N/C]}$$

$$1 \text{ [N/C]} = 1 \text{ [V/m]}$$

$$\langle E \rangle = 3,330,000 \text{ V}$$

(367,000 9V batteries)

What will be his fate?

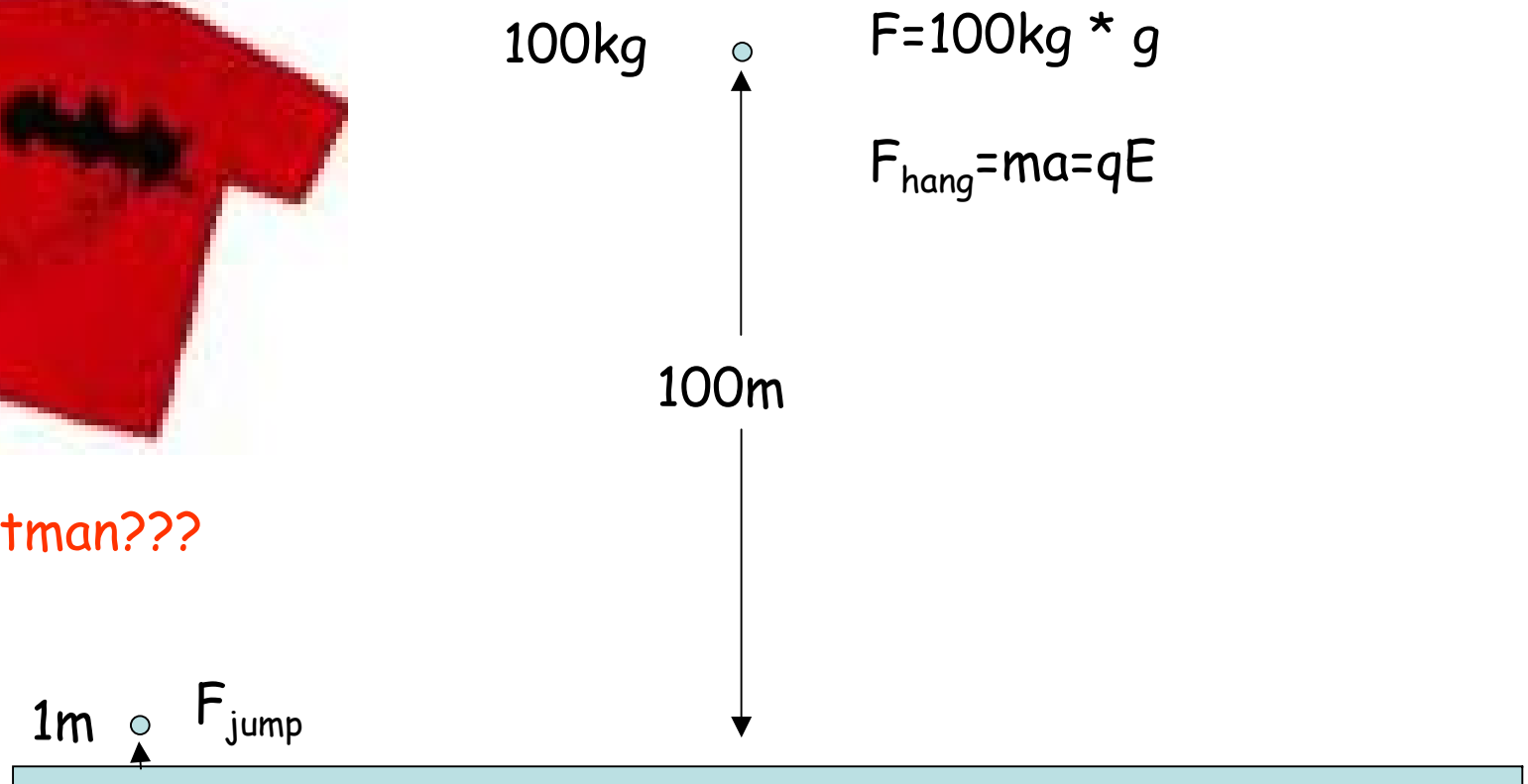
Lightning Man?



# Coulomb Man - Hall of Fame or Shame?



Splatman???



$$F_{\text{jump}} = 10,000 * F_{\text{hang}}!!! = 10,000g$$

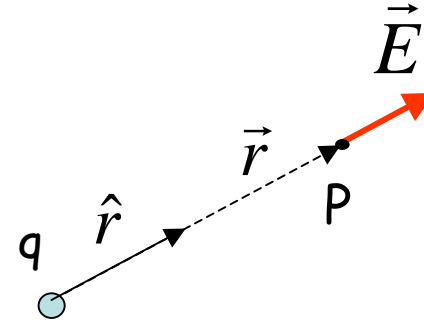
What will be his fate?

# Electric Field Calculations

## Review

$\vec{E}$  for a point charge  $q$ :

$$\vec{E} = \frac{q}{4\pi\epsilon_0 r^2} \hat{r}$$

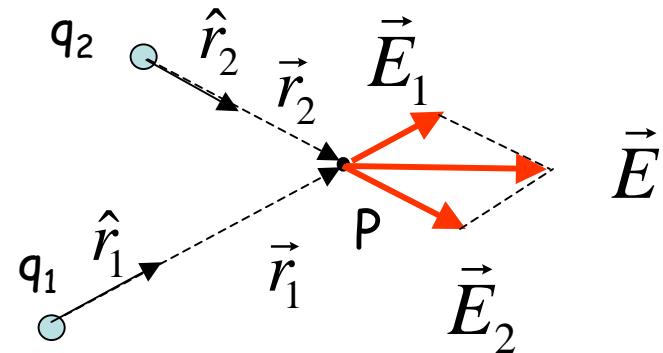


What if more than one charge?

Use superposition.

$$\vec{E} = \frac{q_1}{4\pi\epsilon_0 r_1^2} \hat{r}_1 + \frac{q_2}{4\pi\epsilon_0 r_2^2} \hat{r}_2$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i^2} \hat{r}_i$$



Can do for any number of charges.

# Continuous Charge Distributions

Fun with calculus.

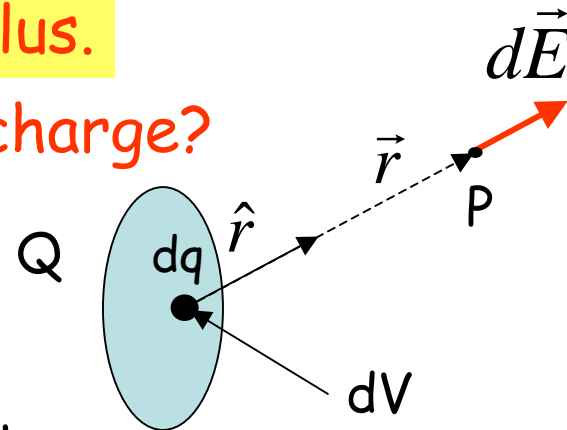
What if we have a distribution of charge?

$Q$  - charge of distribution.

$dq$  - element of charge.

$d\vec{E}$  - contribution to  $\vec{E}$  due to  $dq$ .

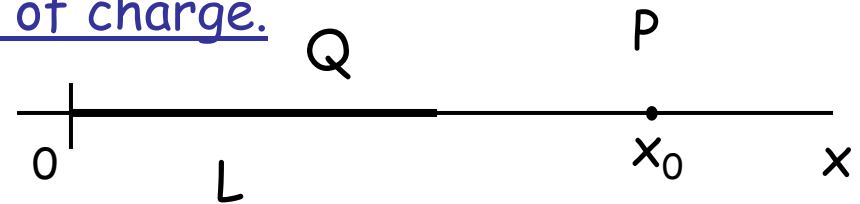
Can write  $dq = \rho dV$ ;  $\rho$  is the charge density.



$$\vec{E} = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i^2} \hat{r}_i \rightarrow \frac{1}{4\pi\epsilon_0} \int_V \frac{dq}{r^2} \hat{r} = \frac{1}{4\pi\epsilon_0} \int_V \frac{\rho dV}{r^2} \hat{r}$$

Example: Field on the axis of a line of charge.

E at P?



Result: 
$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{(x_0 - L)(x_0)} \hat{i}$$

What if  $L \rightarrow 0$ ?

# Charge Densities

- How do we represent the charge “ $Q$ ” on an extended object?

total charge  $Q$   $\longrightarrow$  small pieces of charge  $dq$

- Line of charge:

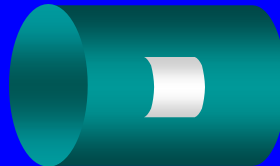
$\lambda$  = charge per unit length



$$dq = \lambda dx$$

- Surface of charge:

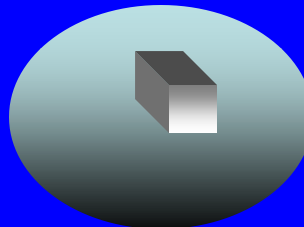
$\sigma$  = charge per unit area



$$dq = \sigma dA$$

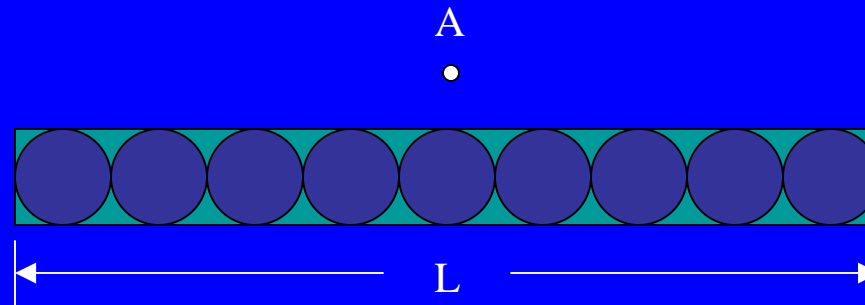
- Volume of Charge:

$\rho$  = charge per unit volume



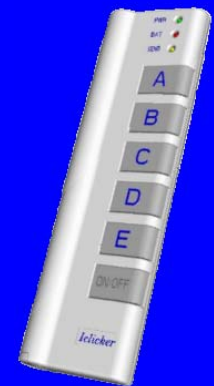
$$dq = \rho dV$$

## Exercise 1:

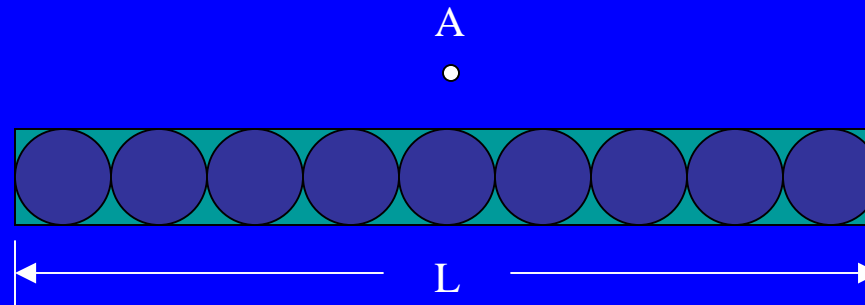


1) A finite line of positive charge is arranged as shown. What is the direction of the Electric field at point A?

- a) up
- b) left
- c) Right
- d) up and left
- e) up and right



## Exercise 1:



1) A finite line of positive charge is arranged as shown. What is the direction of the Electric field at point A?

a) up

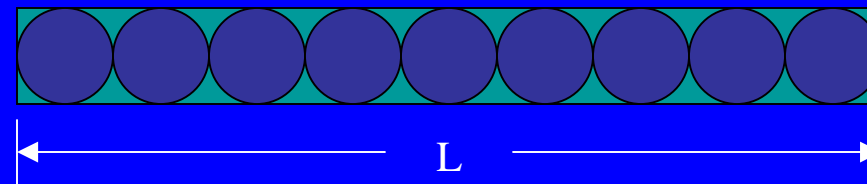
b) left

c) Right

d) up and left

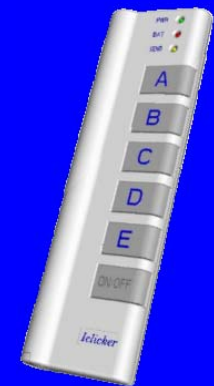
e) up and right

## Exercise 1:

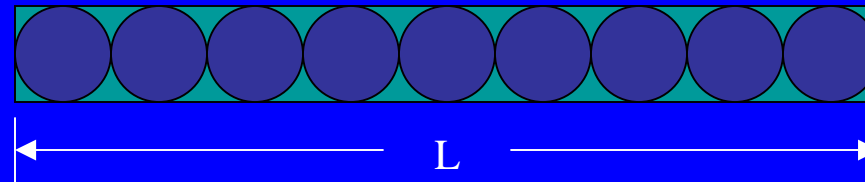


2) What is the direction of the Electric field at point B?

- a) up
- b) left
- c) Right
- d) up and left
- e) up and right



## Exercise 1:



2) What is the direction of the Electric field at point B?

a) up

b) left

c) Right

d) up and left

e) up and right

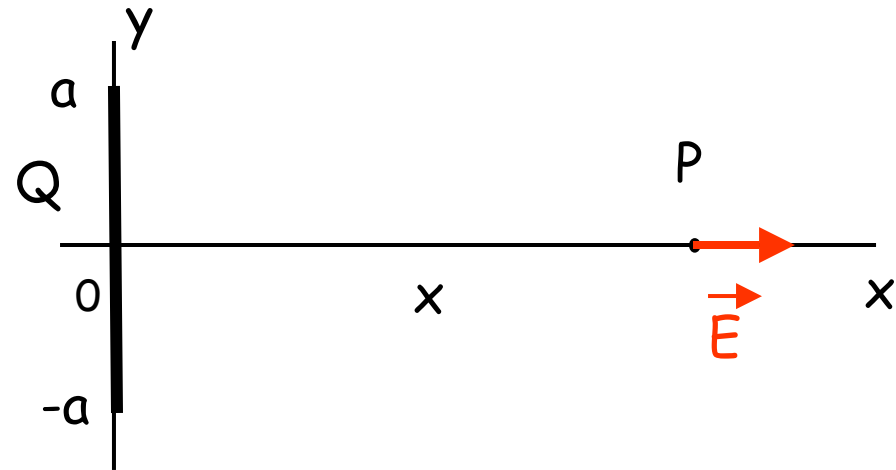
# Continuous Charge Distributions

Example: Field of a line of charge on y axis.

E at P? **Use symmetry.**

Result:

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{x\sqrt{x^2 + a^2}} \hat{i}$$



What if  $a \rightarrow 0$ ?

What if  $a \rightarrow \infty$ ? (Long straight wire)

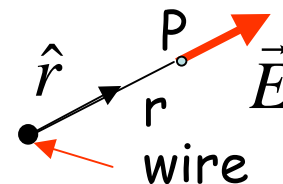
$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{x\sqrt{x^2 + a^2}} \hat{i} = \frac{1}{4\pi\epsilon_0} \frac{Q}{xa\sqrt{(x/a)^2 + 1}} \hat{i}$$

$$\rightarrow \frac{1}{2\pi\epsilon_0} \frac{\lambda}{x} \hat{i}$$

More generally:

$$\vec{E} = \frac{1}{2\pi\epsilon_0} \frac{\lambda}{r} \hat{r}$$

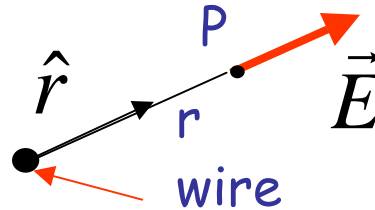
$\lambda = Q/(2a) =$  linear charge density



**Important result:**  
Infinite line of charge

# Infinite Line of Charge

$$\vec{E} = \frac{1}{2\pi\epsilon_0} \frac{\lambda}{r} \hat{r}$$

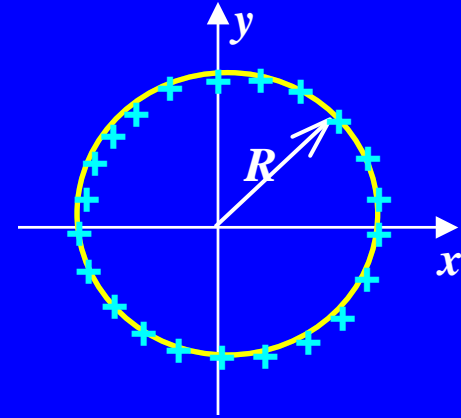


The **Electric Field** produced by an infinite line of charge is:

- everywhere perpendicular to the line
- is proportional to the charge density
- decreases as  $1/r$ .
- later on: **Gauss' Law** makes this clearer

## Exercise 2

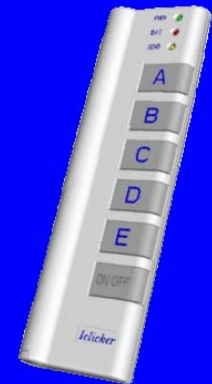
- Consider a circular ring with total charge  $+q$ . The charge is spread uniformly around the ring, as shown, so there is  $\lambda = q/2\pi R$  charge per unit length.
- The electric field at the origin is



(a) zero

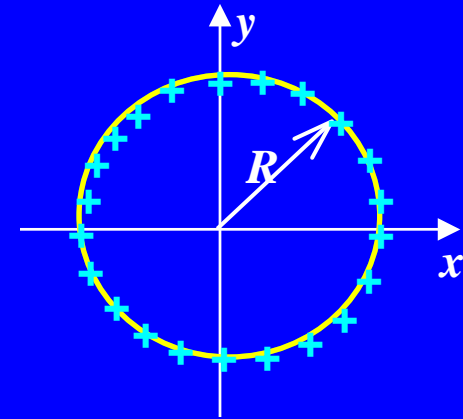
(b)  $\frac{1}{4\pi\epsilon_0} \frac{2\pi\lambda}{R}$

(c)  $\frac{1}{4\pi\epsilon_0} \frac{\pi R\lambda}{R^2}$



## Exercise 2

- Consider a circular ring with total charge  $+q$ . The charge is spread uniformly around the ring, as shown, so there is  $\lambda = q/2\pi R$  charge per unit length.
- The electric field at the origin is



(a) zero

(b)  $\frac{1}{4\pi\epsilon_0} \frac{2\pi\lambda}{R}$

(c)  $\frac{1}{4\pi\epsilon_0} \frac{\pi R\lambda}{R^2}$

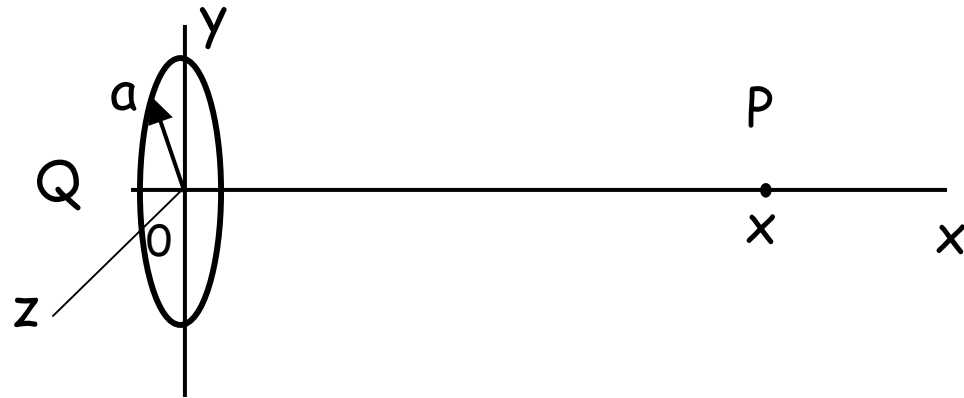
- The key thing to remember here is that the total field at the origin is given by the vector sum of the contributions from all bits of charge.
- If the total field were given by the *algebraic* sum, then (b) would be correct (give it a try) ... but we're dealing with vectors here, *not* scalars!
- Note that the  $E$  field at the origin produced by one bit of charge is exactly cancelled by that produced by the bit of charge diametrically opposite!!
- Therefore, the VECTOR SUM of all these contributions is ZERO!!

# Continuous Charge Distributions

Example: Field on axis of a ring of charge.

E at P?

Here use symmetry.

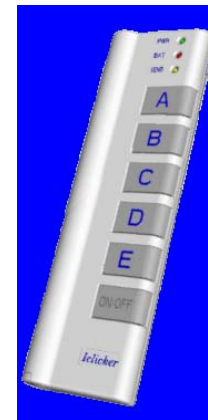


Result:

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Qx}{(x^2 + a^2)^{3/2}} \hat{i}$$

Result for  $x = 0$ ?

Result for  $x \gg a$ ?



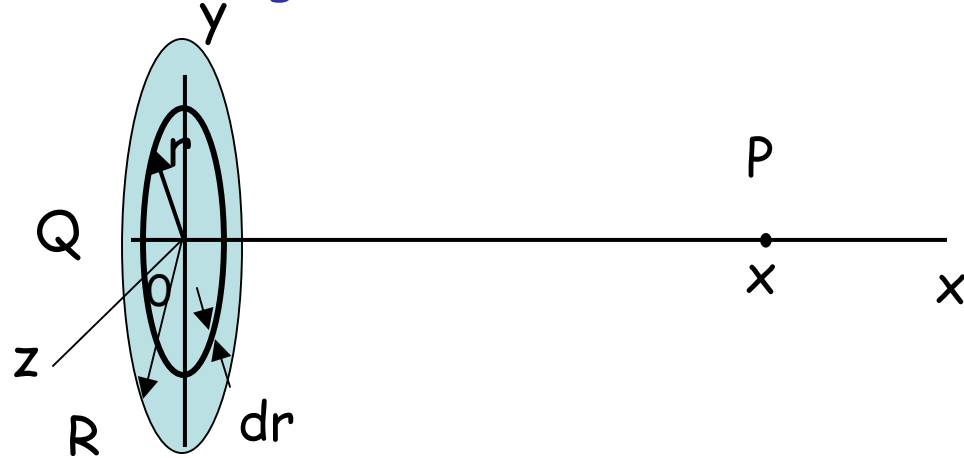
# Continuous Charge Distributions

Example: Field on axis of a disk of charge.

E at P?

How to do?

Integrate over rings of charge.



Result:

$$\vec{E} = \frac{\sigma}{2\epsilon_0} \left[ 1 - \frac{1}{\sqrt{(R^2/x^2) + 1}} \right] \hat{i}$$

$\sigma$  = surface  
charge density  
= charge/area

Result for  $R \rightarrow \infty$ ?

$$\vec{E} = \frac{\sigma}{2\epsilon_0} \left[ 1 - \frac{1}{\sqrt{(R^2/x^2) + 1}} \right] \hat{i} \rightarrow \boxed{\frac{\sigma}{2\epsilon_0} \hat{i}}$$

1. Perpendicular
2. Independent of d.
3. Away/towards.

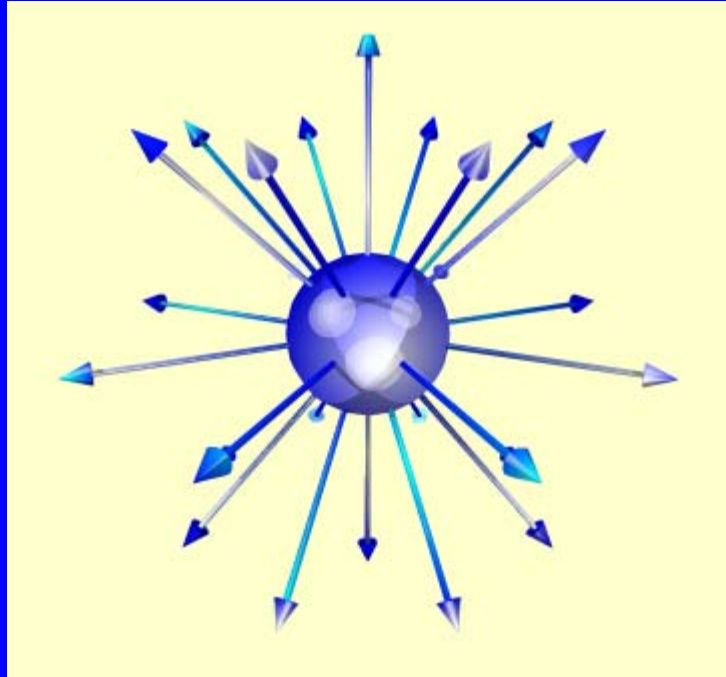
**Important result:** Electric field of an infinite plane of charge.

# Continuous Charge Distributions

## Summary:

1. Have shown that we can use calculus to determine electric fields for a **few special** charge distributions.
2. Method important. Know how to do.
3. Solutions for infinite line of charge and infinite plane important. We will see these again.
4. For most problems, we **cannot** solve them analytically, but we can solve using computer methods.

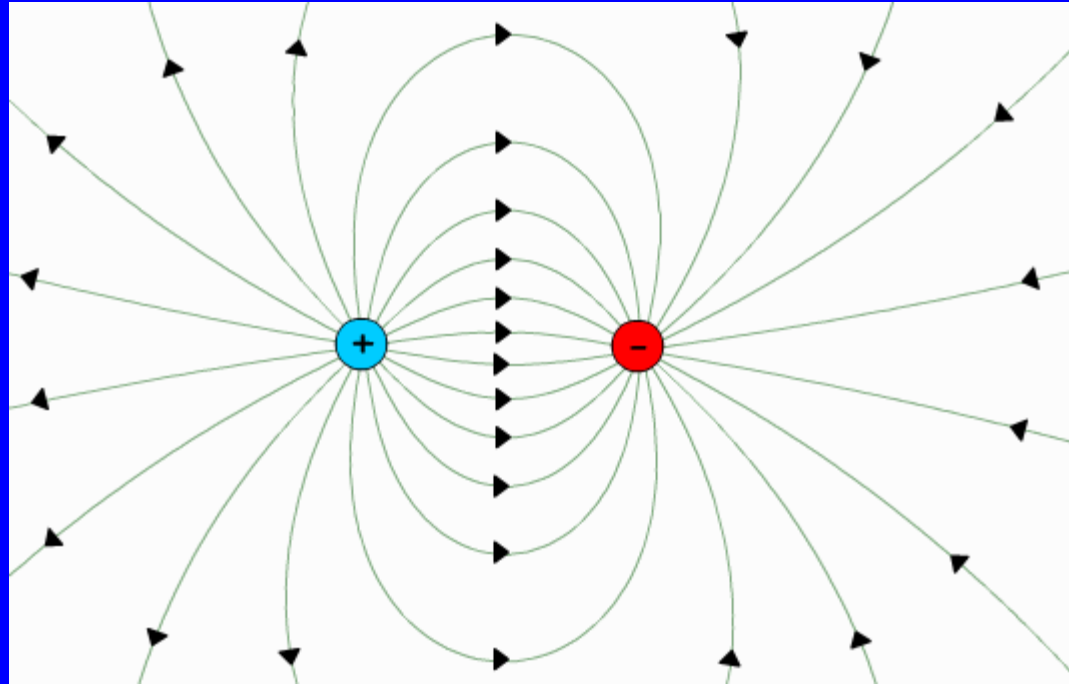
# Electric Field Lines



Direction & Density of Lines  
represent  
Direction & Magnitude of  $E$

Point Charge:  
Direction is radial  
Density  $\propto 1/R^2$

# Electric Field Lines



Dipole Charge Distribution:  
Direction & Density  
much more interesting...

# Weekend fun?

- Get cracking on HW
- You have all you should need to do the HW
- Office Hours immediately after this class (9:30 - 10:00) in WAT214 (? 1-1:30 MWF)
- Other times by arrangement, however
  - My day is very full with meetings
  - If there are structural problems, I can try to arrange an alternative, regular time
- Don't fall behind - first Quiz next week



Spring 2009					
	Monday	Tuesday	Weds	Thurs	Friday
5:00		LAPD			
5:30		general			
6:00		[Argonne]			
6:30					
7:00					
7:30	lecture		lecture		lecture
8:00	prep	lecture	prep	lecture	prep
8:30	PHYS272	prep	PHYS272	prep	PHYS272
9:00	lecture		lecture		lecture
9:30	Off. Hours	PHYS476	Office	PHYS476	Office
10:00		lecture	hours	lecture	hours
10:30	ANITA	xFEL			xFEL
11:00	[Collab]	mtg	LAPD	ASIC	FEL
11:30		prep	EE	work	science
12:00		Lunch	[EFI]	Lunch	
12:30	Lunch	PHYS476	Lunch		Lunch
13:00	ID Lab	Lab		PHYS476	
13:30	Facilities	FEL	LAPD	Lab.	ASIC
14:00	AMBER	PI's mtg	work		work
14:30	Group	Pixel det	STURM		Belle
15:00	DAQ	Group	xTOP		local
15:30	ITOP		mech	Physics	analysis
16:00	PHYS476	Pixel det	[Nagoya]	Dept.	meeting
16:30	Lab	work	ITOP	Colloq.	
17:00	prep		prep	fDIRC	
17:30				CRT mtg	TG's
18:00					
18:30					
19:00					
19:30					
20:00					
20:30					
21:00			Belle2		
21:30			PID		
22:00			[KEK]		

# Continuous Charge Distributions

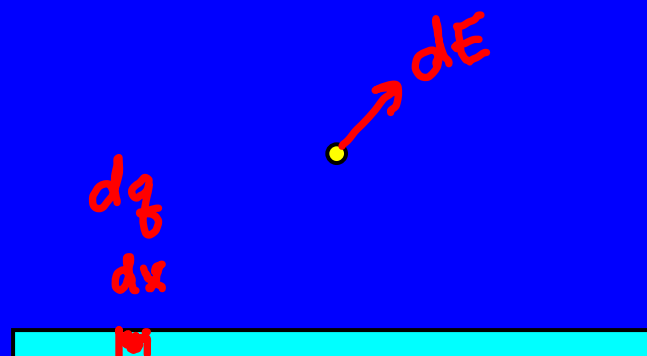
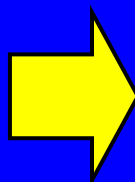
"What the integrals have to do with the force of the electric field... Are the integrals actually necessary for understanding this? "

**YOU BETCHA !**

Summation becomes an integral (be careful with vector nature)

Symmetry is often helpful

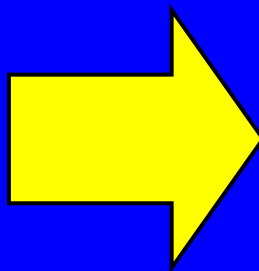
Linear charge density is often useful



$$\lambda = Q/L \quad dq = \lambda dx$$

$\frac{C}{m}$     $m$

$$\vec{E} = \sum_i k \frac{Q_i}{r_i^2} \hat{r}_i$$



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

$\frac{1}{r^2}$     $\hat{r}$