Welcome To

Physics 8.02T

For now, please sit anywhere, 9 to a table

Class 1: Outline

Hour 1:

Why Physics?

Why Studio Physics? (& How?)

Vector and Scalar Fields

Hour 2:

Gravitational fields

Electric fields

Why Physics?

Why Study Physics?

Understand/appreciate nature

- Lightning
- Soap Films
- Butterfly Wings
- Sunsets

Why Study Physics?

Electromagnetic phenomena led directly to Einstein's discovery of the nature of space and time, see his paper

ON THE ELECTRODYNAMICS OF MOVING BODIES

A. Einstein June 30, 1905

In the last class of the term before the review, we will explain to you how this comes about

Why Study Physics?

- Understand/Appreciate Nature
- Understand Technology
  - Electric Guitar
  - Ground Fault Interrupts
  - Microwave Ovens
  - Radio Towers

Why Study Physics?

- Understand/Appreciate Nature
- Understand Technology
- Learn to Solve Difficult Problems
- It’s Required

Why Studio Physics?

Why The TEAL/Studio Format?

Problems with Large Lectures:

Lecture/recitations are passive

No labs → lack of physical intuition

E&M is abstract, hard to visualize

TEAL/Studio Addresses Problems:

Lectures → Interactive, Collaborative Learning

Incorporates desk top experiments

Incorporates visualization/simulations

Bottom Line: Learn More, Retain More, Do Better

Why The TEAL/Studio Format?

By standard assessment measures, TEAL shows a factor of two increase in learning gains as compared to lecture/recitation format

(see Dori and Belcher, "How Does TEAL Affect Student Learning of E&M Concepts?", *Journal of the Learning Sciences* 14(2) 2004.)

Bottom Line: Learn More, Retain More, Do Better

Overview of TEAL/Studio

Collaborative Learning

Groups of 3, Tables of 9

You teach, you discuss, you learn

In-Class Problem Solving

Desktop Experiments

Teacher-Student Interaction

Visualizations

PRS Questions

Personal Response System (PRS) Question: Physics Experience

Pick up the nearest PRS (under the table in a holder)

Your Responsibilities

Before Class:

Read Summary

In Class: (You must be present for credit)

Problem Solving, Desktop Experiments, PRS

After Class:

Read Study Guide, Review Visualizations

Homework (Tuesdays 4:15 pm)

Exams

3 Midterms (45%) + Final (25%)

To Encourage Collaboration, Grades Are NOT Curved In 8.02:

	+		-
A	>=95	<95 & >=90	<90 & >=85
B	<85 & >=80	<80 & >=75	<75 & >=70
C	<70 & >=67	<67 & >=64	<64 & >=60
D		<60 & >=55	
F		<55	

Honesty Issues

Problem Sets:

Please work together BUT

Submit your own, uncopied work

In Class Assignments:

Must sign your own name to submitted work

Signing another's name is COD offense

PRS:

Use only your assigned PRS

Using another's PRS is COD offense

Physics 8.02 Staff

Includes:

- Lecturer
- Demo Group
- Graduate TA
- UGrad TAs

Textbooks

Required:

"Introduction to E & M"

Liao, Dourmashkin, and Belcher

Supplemental (not required):

Serway & Jewett 6th Edition; Giancoli; …

Prefer something else? Let me know!

Important: Find something you can read

Common Questions & Answers

- Dysfunctional Group?
- Must Miss Class?
- Must Miss HW?
- Must Miss Exam?

- Tell Grad TA
- Tell Grad TA
- Tell Grad TA
- Tell me ASAP

Exam dates & times are online

Do NOT schedule early vacation departures, etc. without consulting these times!

Any Questions?

Physics is not Math…

...but we use concepts from 18.02

- Gradients $\vec{\mathbf{E}} = -\nabla V$
- Path Integrals $\Delta V \equiv -\int_A^B \vec{\mathbf{E}} \cdot d\,\vec{\mathbf{s}}$
- Surface Integrals $\underset{S}{\oiint} \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \dfrac{Q_{in}}{\varepsilon_0}$
- Volume Integrals $Q = \iiint \rho\, dV$

PRS Question:
Math Background

Don’t Worry!

- For many this is new & I will introduce concepts before use (yell at me if not!)
- Concepts are VERY important – mechanics are almost trivial

Math introduction/review:

A time will be scheduled
Presentation slides will be posted

So what physics do we learn in 8.02 anyway????

What's the Physics?

8.01: Intro. to basic physics concepts: motion, force, energy, …

How does matter interact?

Four Fundamental Forces:

Long range: Gravity (8.01 … Gen.Relativity)

Short Range: Strong and Weak

Mid Range: Electromagnetic (8.02)

8.02: Electricity and Magnetism

Also new way of thinking…

How do objects interact at a distance?

Fields We will learn about E & M Fields: how they are created & what they effect

---

Big Picture Summary:

Maxwell Equations:

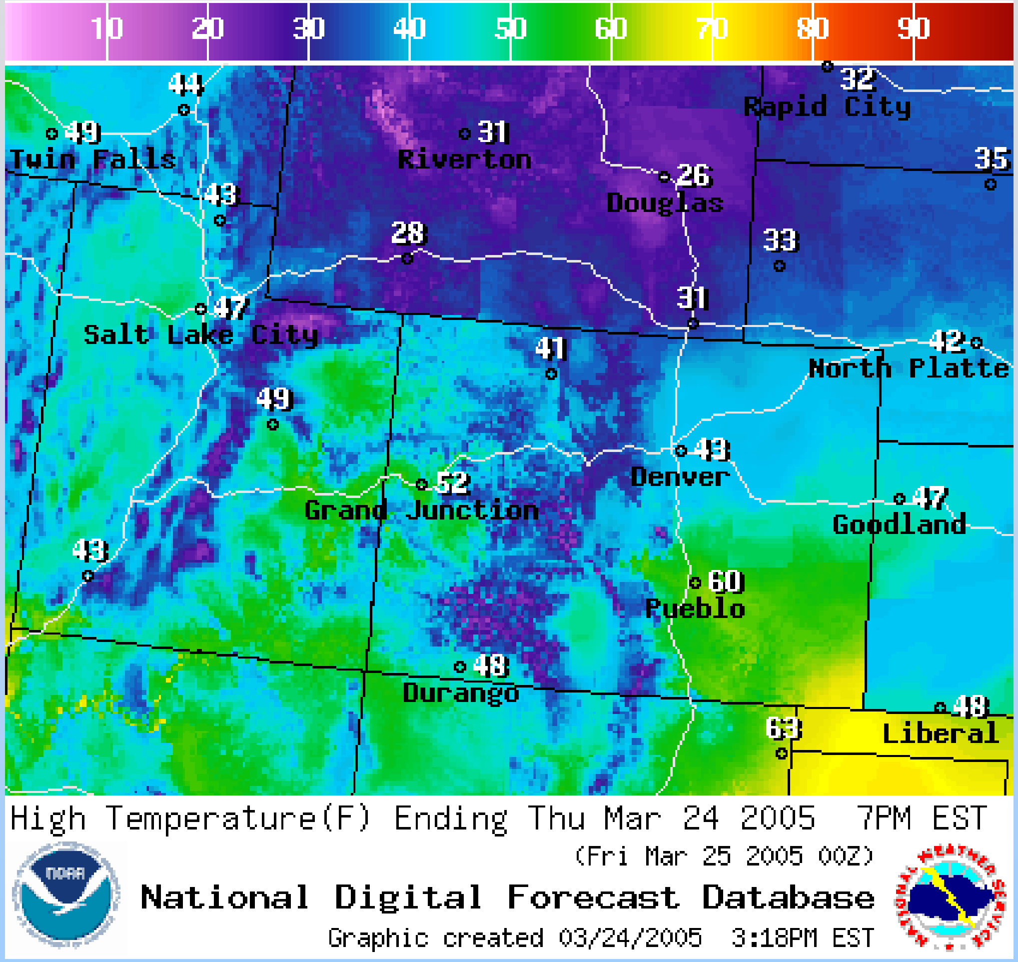
$$\oiint_S \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{Q_{in}}{\varepsilon_0} \qquad \oint_C \vec{\mathbf{E}} \cdot d\,\vec{\mathbf{s}} = -\frac{d\Phi_B}{dt}$$

$$\oiint_S \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0 \qquad \oint_C \vec{\mathbf{B}} \cdot d\,\vec{\mathbf{s}} = \mu_0 I_{enc} + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

Lorentz Force: $\vec{\mathbf{F}} = q\left(\vec{\mathbf{E}} + \vec{\mathbf{v}} \times \vec{\mathbf{B}}\right)$

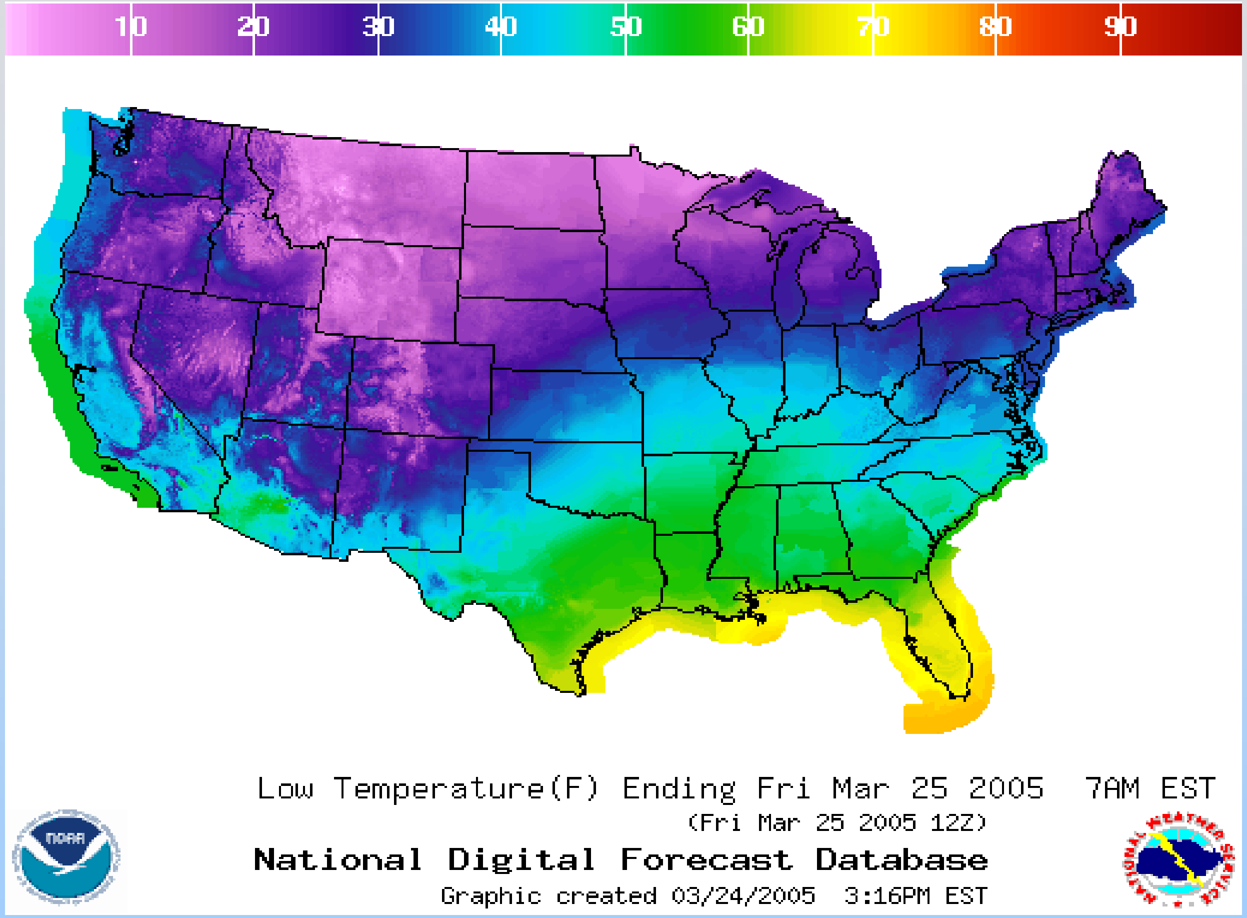
Today: Fields
In General, then
Gravitational & Electric

Scalar Fields



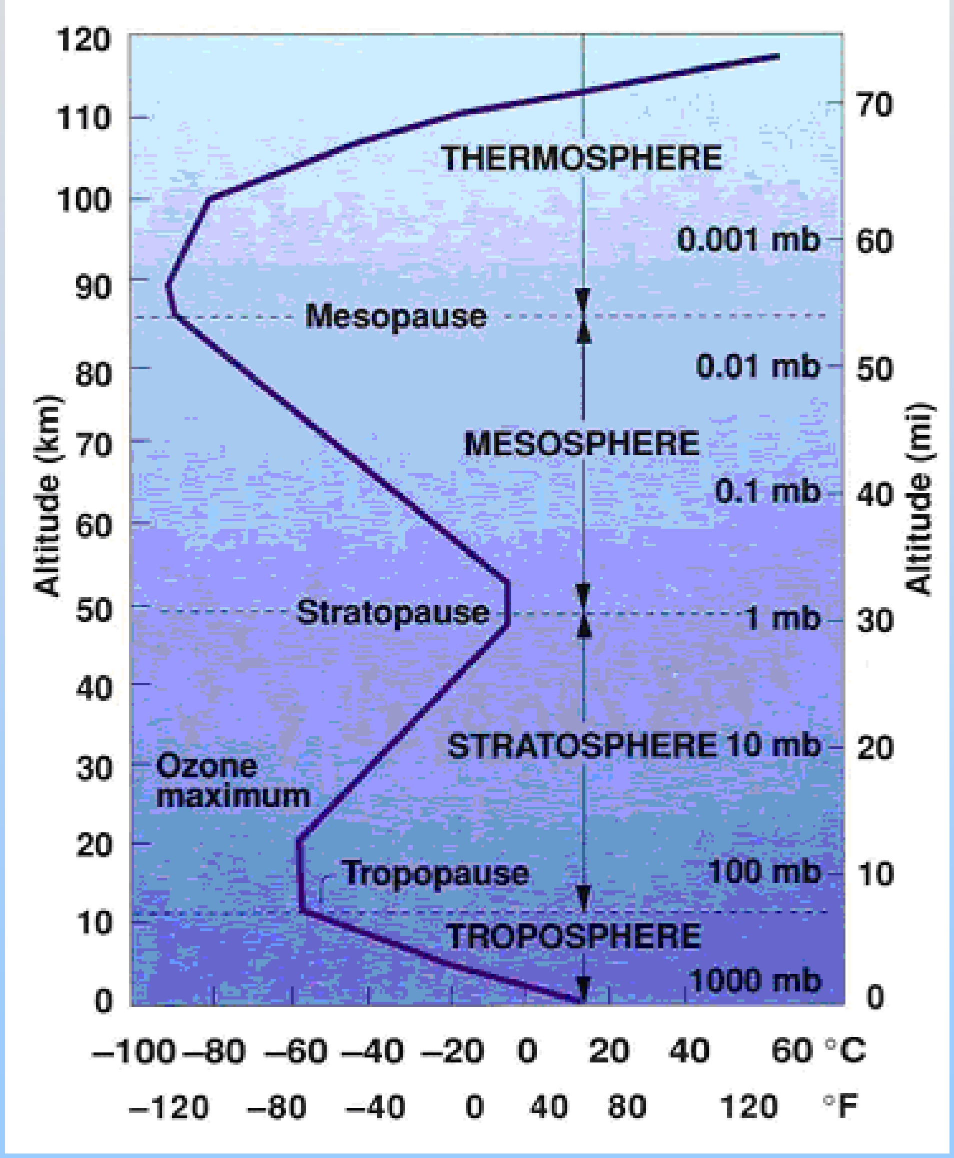
e.g. Temperature: Every location has associated value (number with units)

Scalar Fields - Contours



- Colors represent surface temperature
- Contour lines show constant temperatures

Fields are 3D

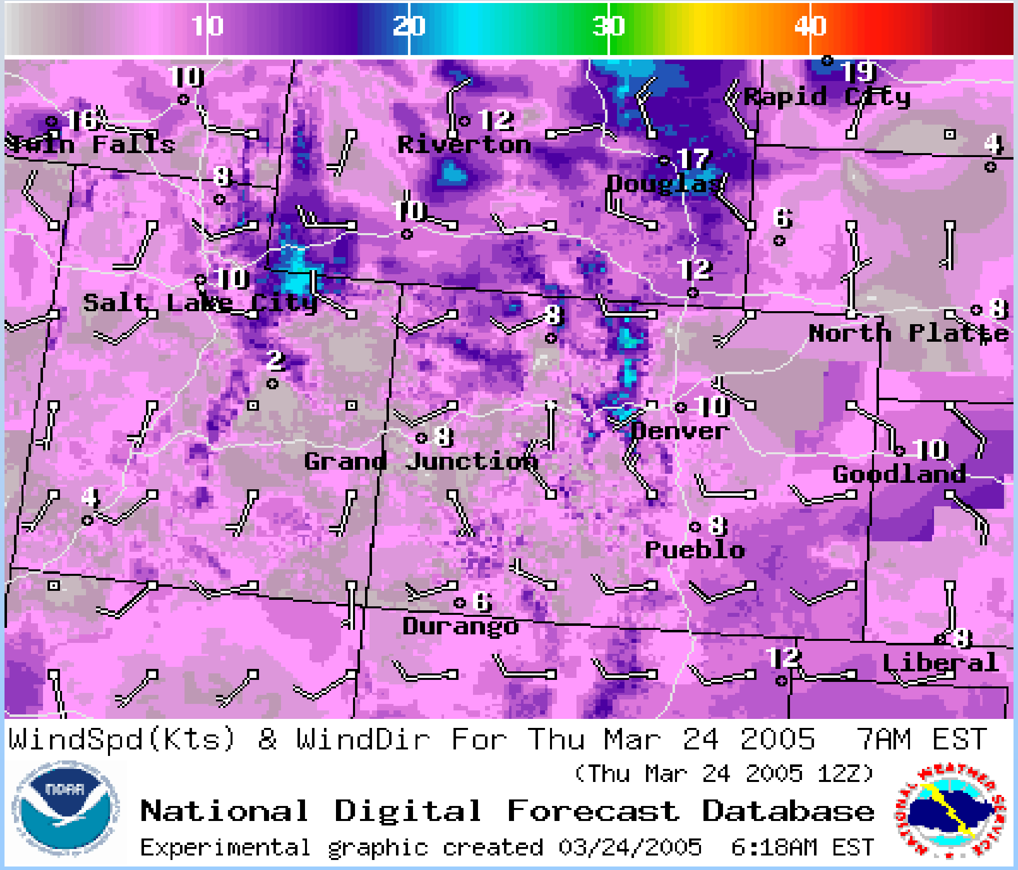


- T = T(x,y,z)
- Hard to visualize

→ Work in 2D

Vector Fields

Vector (magnitude, direction) at every point in space



Example: Wind Velocity Vector Field

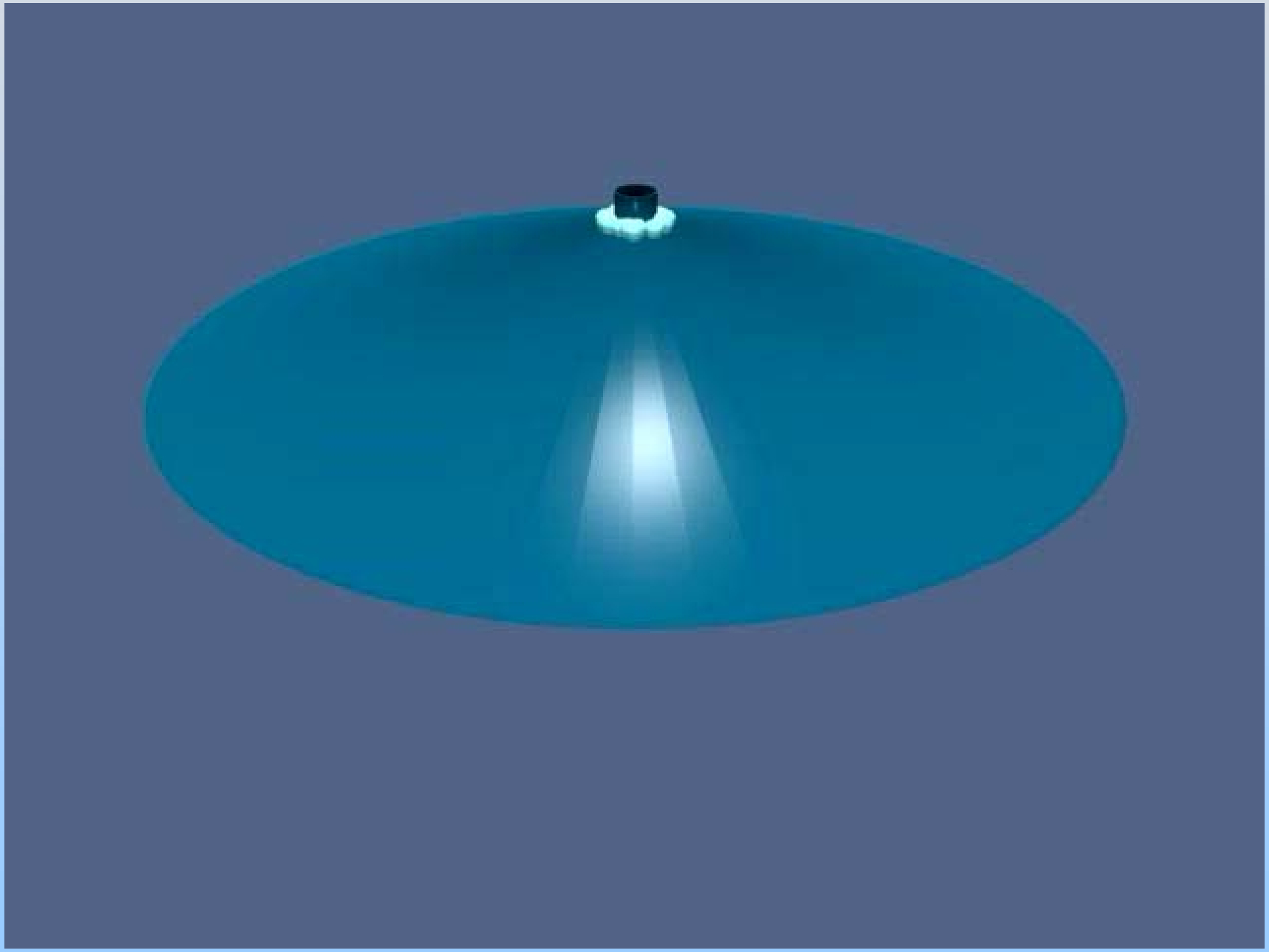
Vector Field Examples

Begin with Fluid Flow

Vector Field Examples

Flows With Sources

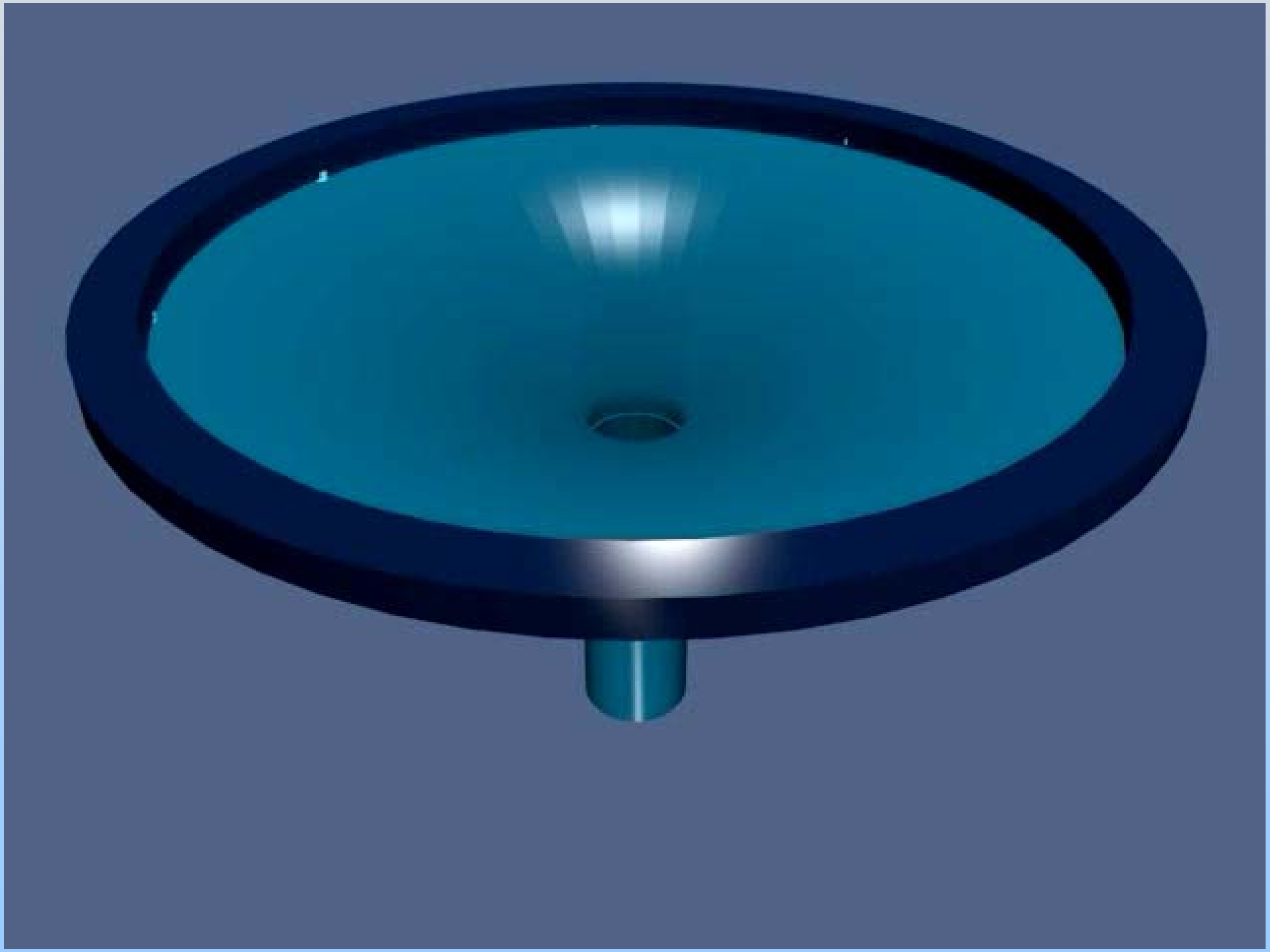
(http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/vectorfields/02-particleSource/02-ParticleSource_320.html)



Vector Field Examples

Flows With Sinks

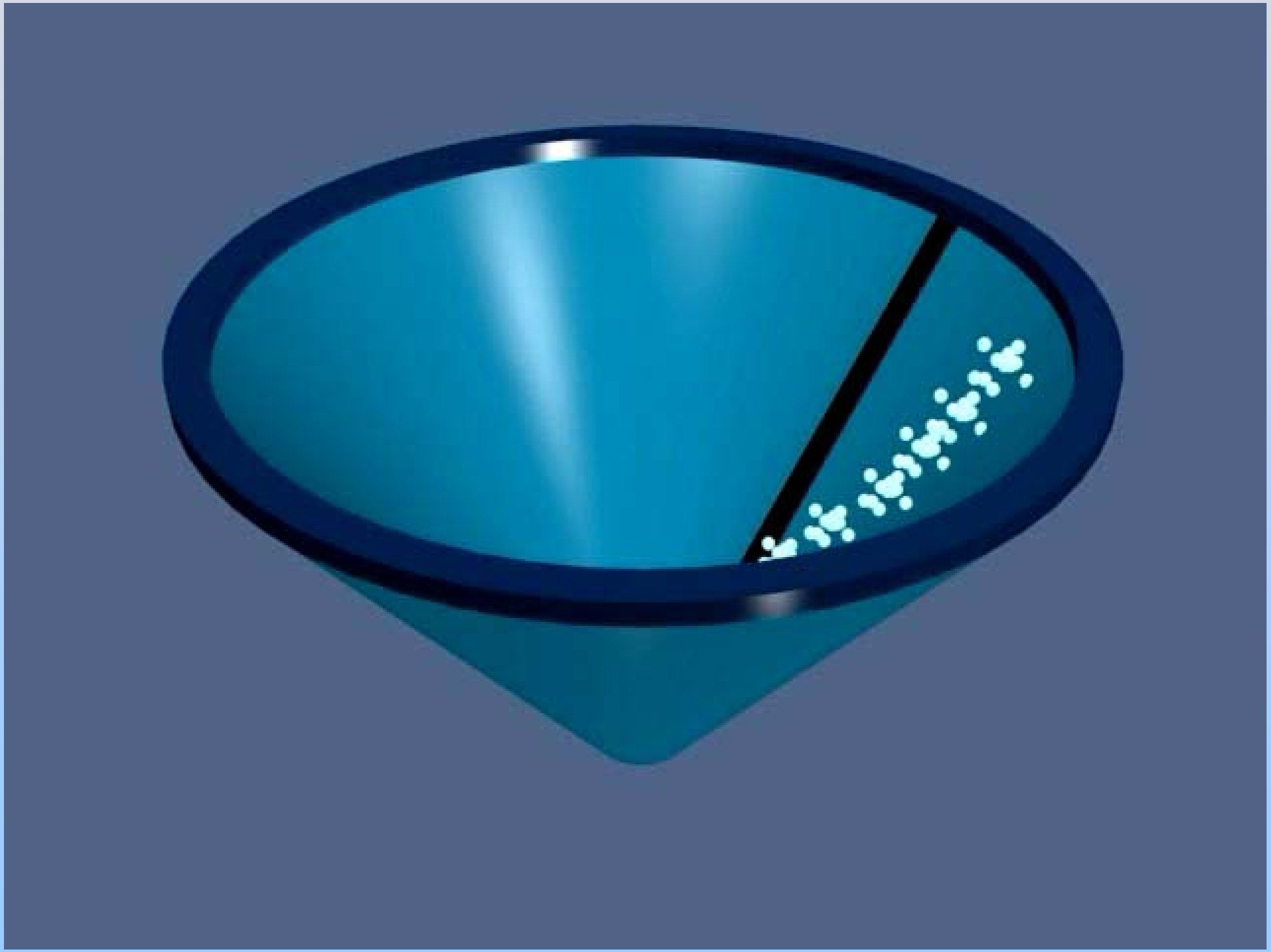
(http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/vectorfields/01-particleSink/01-ParticleSink_320.html)



Vector Field Examples

Circulating Flows

(http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/vectorfields/03-particleCirculate/03-PartCircMotion_320.html)



Visualizing Vector Fields: Three Methods

Vector Field Diagram

Arrows (different colors or length) in direction of field on uniform grid.

Field Lines

Lines tangent to field at every point along line

Grass Seeds

Textures with streaks parallel to field direction

All methods illustrated in

http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/electrostatics/39-pcharges/39-twocharges320.html

Vector Fields – Field Lines

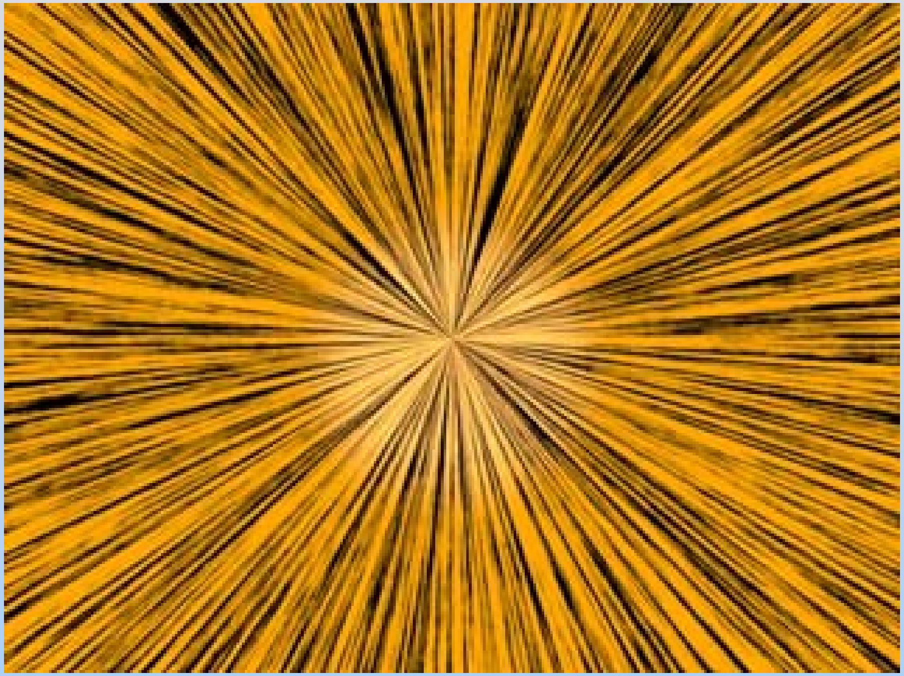
- Direction of field line at any point is tangent to field at that point
- Field lines never cross each other

PRS Question: Vector Field

In General: Don't pick up unit until ready to answer

Then I'll know when class is ready

Vector Fields – "Grass Seeds"



Source/Sink

Circulating

Although we don't know absolute direction, we can determine relative direction

PRS Questions:
“Grass Seed” Visualizations

Weird Field Contest

Purpose

Gain familiarity with vector fields

Winner

Displayed in MIT Museum Exhibit

Due Date

Turn in with 2nd PSet in Separate Box

Another Vector Field: Gravitational Field

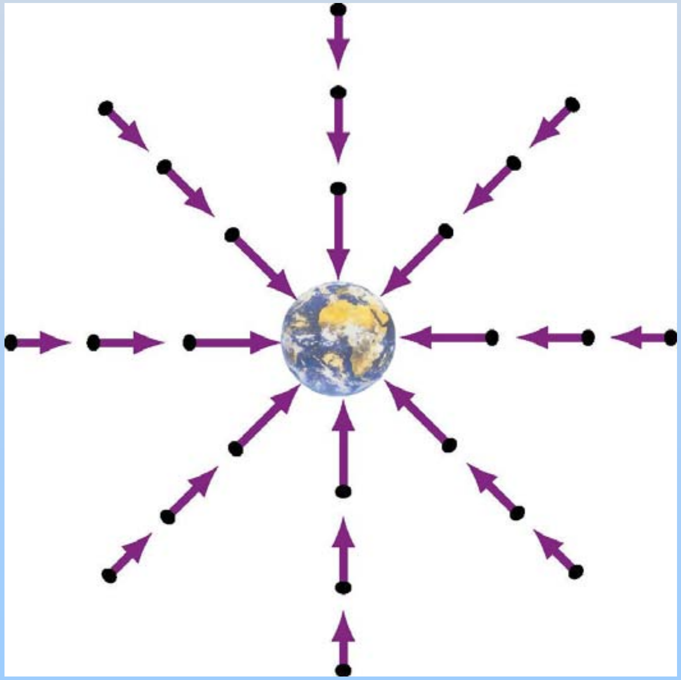
Example Of Vector Field: Gravitation

Gravitational Force:

$$\vec{\mathbf{F}}_g = -G\frac{Mm}{r^2}\hat{\mathbf{r}}$$

Gravitational Field:

$$\boxed{\vec{\mathbf{g}} = \frac{\vec{\mathbf{F}}_g}{m} = -\frac{GMm/r^2}{m}\hat{\mathbf{r}} = -G\frac{M}{r^2}\hat{\mathbf{r}}}$$



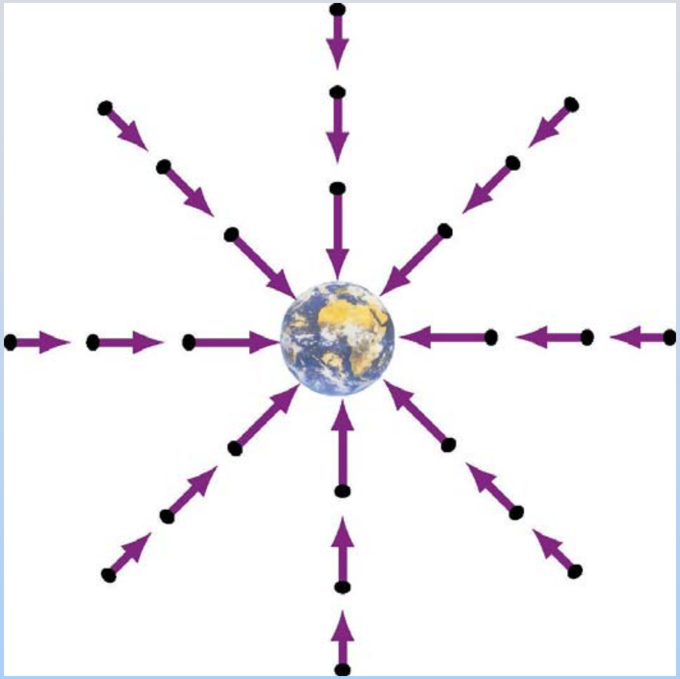
M : Mass of Earth

Example Of Vector Field: Gravitation

Gravitational Field:

$$\vec{\mathbf{g}} = -G\frac{M}{r^2}\hat{\mathbf{r}} \qquad \vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$$

Created by M   *Felt* by m

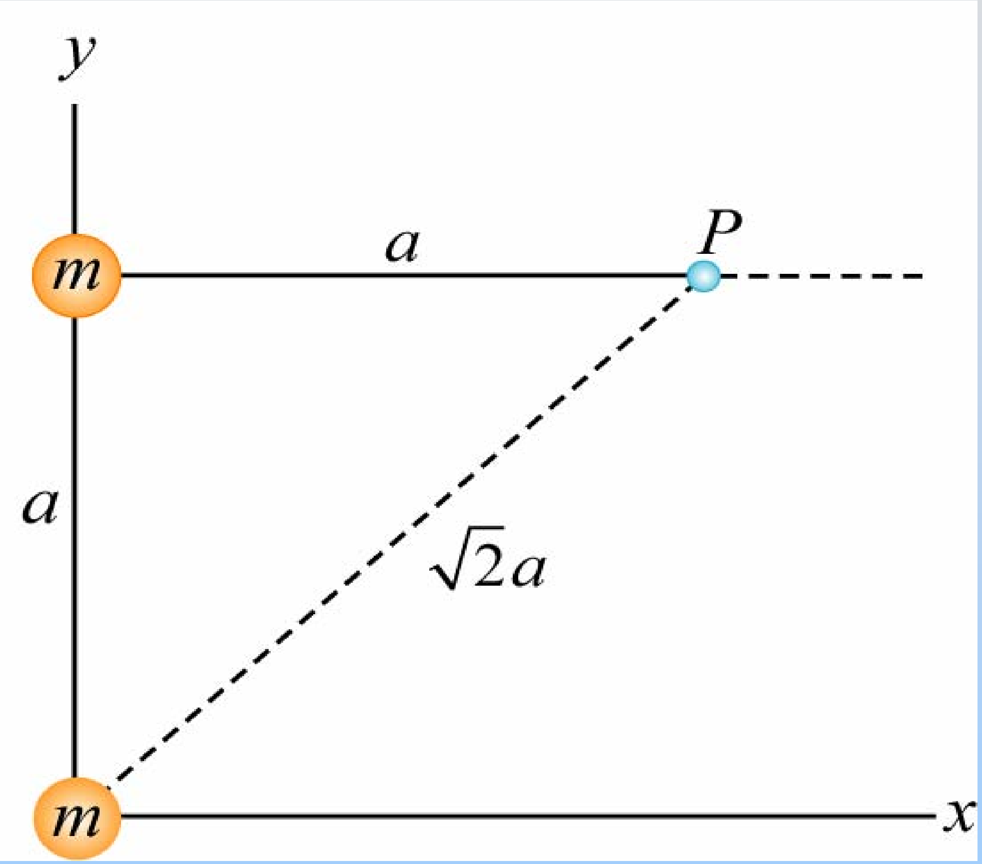


M : Mass of Earth

$\hat{\mathbf{r}}$: unit vector from M to m

$$\hat{\mathbf{r}} = \frac{\vec{\mathbf{r}}}{r} \quad \Rightarrow \vec{\mathbf{g}} = -G\frac{M}{r^3}\vec{\mathbf{r}}$$

In Class Problem



Find the gravitational field $\vec{\mathbf{g}}$ at point P

Bonus: Where would you put another mass m to make the field $\vec{\mathbf{g}}$ become 0 at P?

NOTE: Solutions will be posted within one day of class

From Gravitational to Electric Fields

Electric Charge (~Mass)

Two types of electric charge: positive and negative

Unit of charge is the ***coulomb*** [C]

Charge of electron (negative) or proton (positive) is

$$\pm e, \qquad e = 1.602 \times 10^{-19} C$$

Charge is quantized

$$Q = \pm Ne$$

Charge is conserved

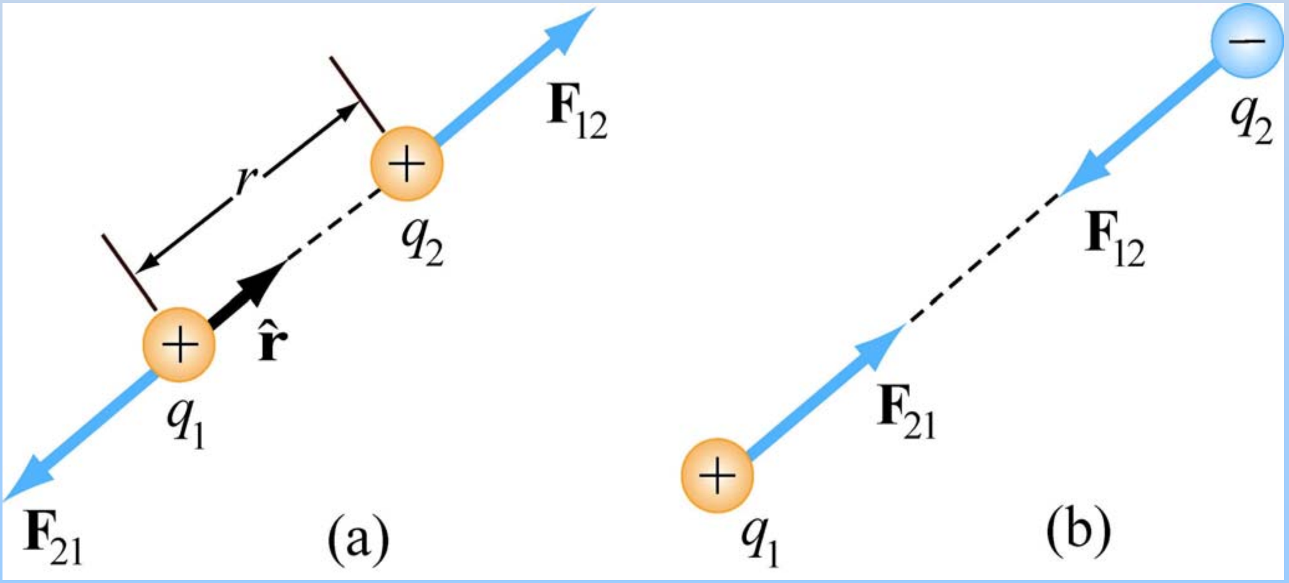
$$n \rightarrow p + e^{-} + \bar{\nu} \qquad e^{+} + e^{-} \rightarrow \gamma + \gamma$$

Electric Force (~Gravity)

The electric force between charges q_1 and q_2 is

(a) repulsive if charges have same signs

(b) attractive if charges have opposite signs

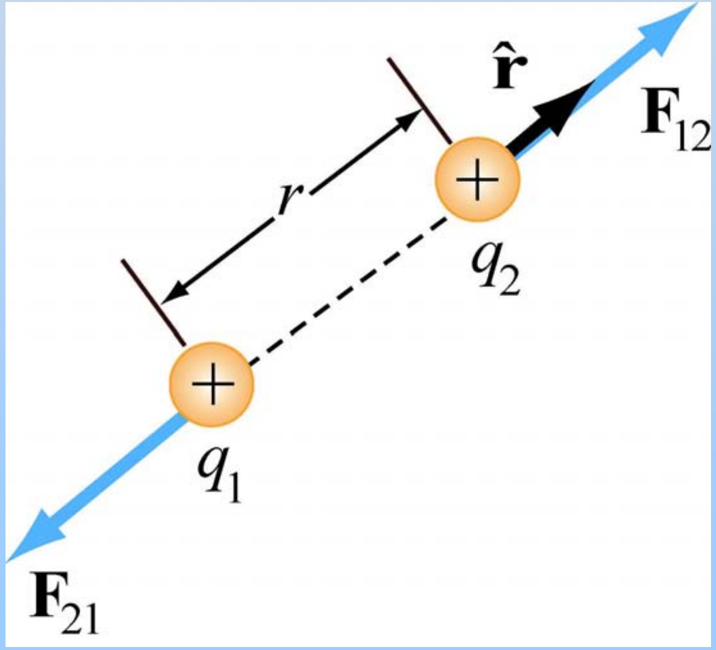


Like charges repel and opposites attract !!

Coulomb's Law

Coulomb's Law:
Force by q_1 on q_2

$$\boxed{\vec{\mathbf{F}}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}}$$

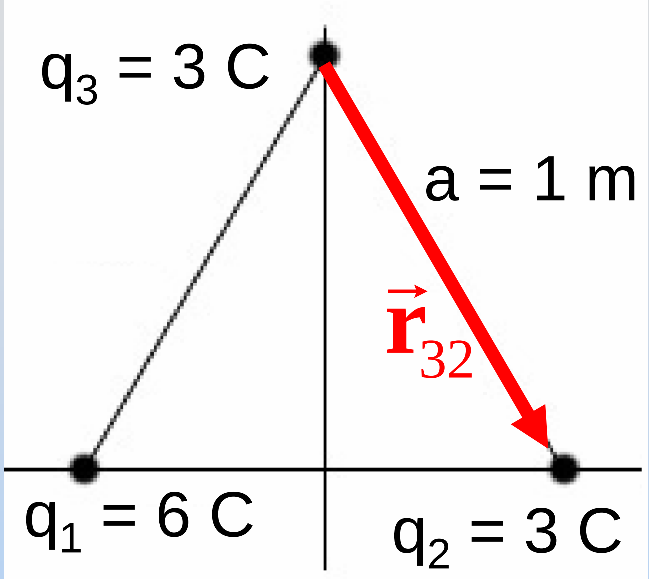


$$k_e = \frac{1}{4\pi\varepsilon_0} = 8.9875 \times 10^9 \text{ N m}^2/\text{C}^2$$

$\hat{\mathbf{r}}$: unit vector from q_1 to q_2

$$\hat{\mathbf{r}} = \frac{\vec{\mathbf{r}}}{r} \Rightarrow \vec{\mathbf{F}}_{12} = k_e \frac{q_1 q_2}{r^3} \vec{\mathbf{r}}$$

Coulomb's Law: Example



$$\vec{\mathbf{F}}_{32} = ?$$

$$\vec{\mathbf{r}}_{32} = \left(\tfrac{1}{2}\,\hat{\mathbf{i}} - \tfrac{\sqrt{3}}{2}\,\hat{\mathbf{j}}\right)\ \mathrm{m}$$

$$r = 1\mathrm{m}$$

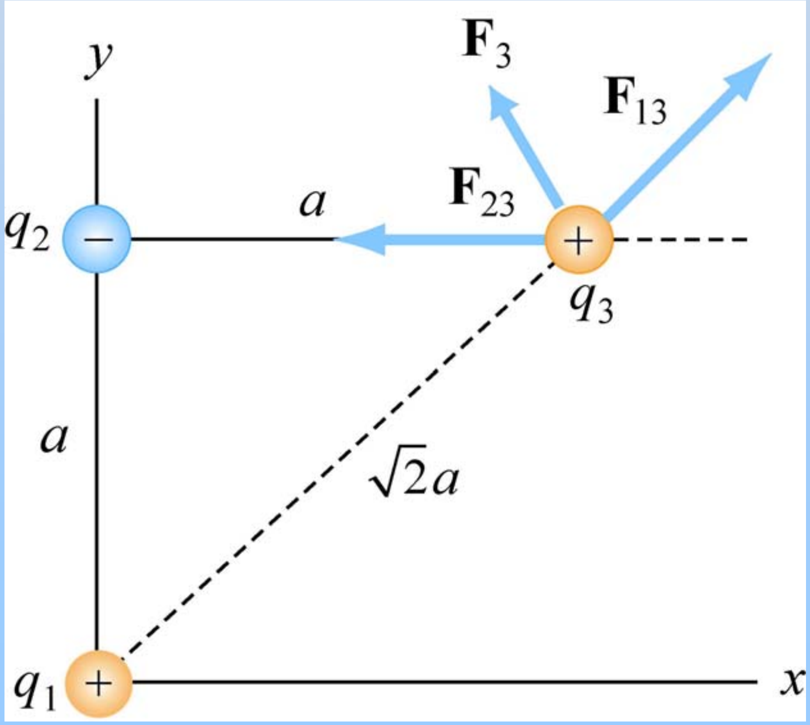
$$\vec{\mathbf{F}}_{32} = k_e q_3 q_2 \frac{\vec{\mathbf{r}}}{r^3} = \left(9\times10^9\,\mathrm{N\,m^2/C^2}\right)(3\mathrm{C})(3\mathrm{C})\frac{\frac{1}{2}\left(\hat{\mathbf{i}}-\sqrt{3}\hat{\mathbf{j}}\right)\mathrm{m}}{(1\mathrm{m})^3}$$

$$= \frac{81\times10^9}{2}\left(\hat{\mathbf{i}}-\sqrt{3}\hat{\mathbf{j}}\right)\ \mathrm{N}$$

The Superposition Principle

Many Charges Present:
Net force on any charge is vector sum of forces from other individual charges

Example:



$$\vec{\mathbf{F}}_3 = \vec{\mathbf{F}}_{13} + \vec{\mathbf{F}}_{23}$$

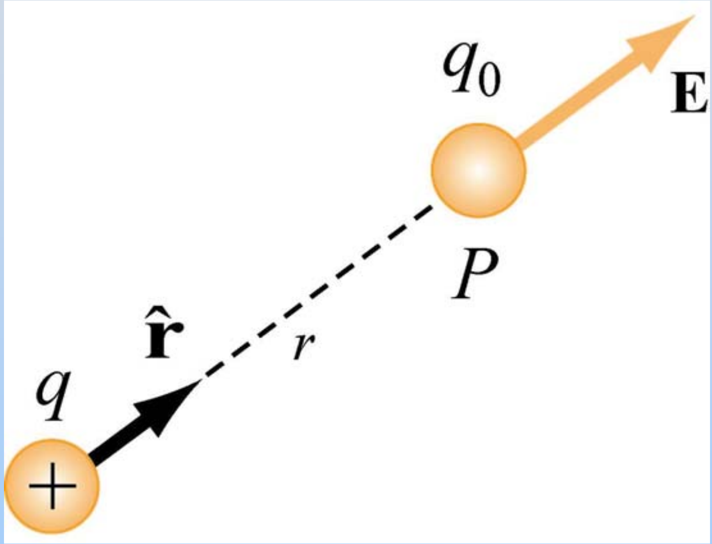
In general:

$$\boxed{\vec{\mathbf{F}}_j = \sum_{i=1}^{N} \vec{\mathbf{F}}_{ij}}$$

Electric Field (~g)

The electric field at a point is the force acting on a test charge q_0 at that point, divided by the charge q_0 :

$$\vec{\mathbf{E}} \equiv \frac{\vec{\mathbf{F}}}{q_0}$$



For a point charge q:

$$\vec{\mathbf{E}} = k_e \frac{q}{r^2}\hat{\mathbf{r}}$$

http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/electrostatics/04-MovingChargePosElec/04-MovChrgPosElec_f223_320.html

Superposition Principle

The electric field due to a collection of *N* point charges is the vector sum of the individual electric fields due to each charge

$$\vec{\mathbf{E}}_{total} = \vec{\mathbf{E}}_1 + \vec{\mathbf{E}}_2 + \ldots\ldots = \sum_{i=1}^{N} \vec{\mathbf{E}}_i$$

Summary Thus Far

	Mass M	Charge q (±)
CREATE:	$\vec{\mathbf{g}} = -G\dfrac{M}{r^2}\hat{\mathbf{r}}$	$\vec{\mathbf{E}} = k_e\dfrac{q}{r^2}\hat{\mathbf{r}}$
FEEL:	$\vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$	$\vec{\mathbf{F}}_E = q\vec{\mathbf{E}}$

This is easiest way to picture field

PRS Question: Electric Field