Lecture 05: 01/30/2024

- Announcements
  Written HW#2 due midnight tonight
  Written HW#2 due Friday
  Special zoom review session at 7 pm tonight

- Last Time
  - Coulomb's Law
  - Solving problems by adding vectors geometrically
  - Introduction to r-hat

- Today
  - Coulomb's Law
    Coulomb vector form and r-hat
    Electric field
    Electric field lines

SCHEDULE

#	Dates	Reading	Topic	Lab.
1	Jan 16	B1Ch16	Intro, Waves ($v = f\lambda$, $v = \sqrt{T/\mu}$)	no lab
2	Jan 18		Superposition, Standing Waves	
3	Jan 23	B2Ch5	$F = q_1 q_2 / r^2 \hat{r}$, conductors/insulators	Wave Superposition
4	Jan 25		$\vec{E}$-field concept and multi-Q	
5	Jan 30	Ch 5	Field lines and dipoles	Oscilloscope
6	Feb 1	Ch 5	Flux concept and Gauss Law	
7	Feb 6	Ch 6	Field of line, point, plane	Coulomb's Law
8	Feb 8	Ch 6	Gaussian tricks!	
9	Feb 13	Ch 7	PE and Electric Potential	E-field and Superposition
10	Feb 15	Ch 7	$V = \int \vec{E} \cdot d\vec{s}$	
11	Feb 20		V for multi charges	Electric Field Mapping
12	Feb 22		Test 1	
13	Feb 27	Ch 8	Capacitance	Capacitors and Delectrics
14	Feb 29	Ch 8	Capacitance	
15	Mar 5	Ch 9	Current and Resistance	Ohm's Law
16	Mar 7	Ch 9	Current and Resistance	
17	Mar 12	Ch 10	DC Circuits	Kirchoff's Laws
18	Mar 14	Ch 10	Magnetic Forces & Fields	
	Mar 19/21		Spring Break	

Coulomb's Law

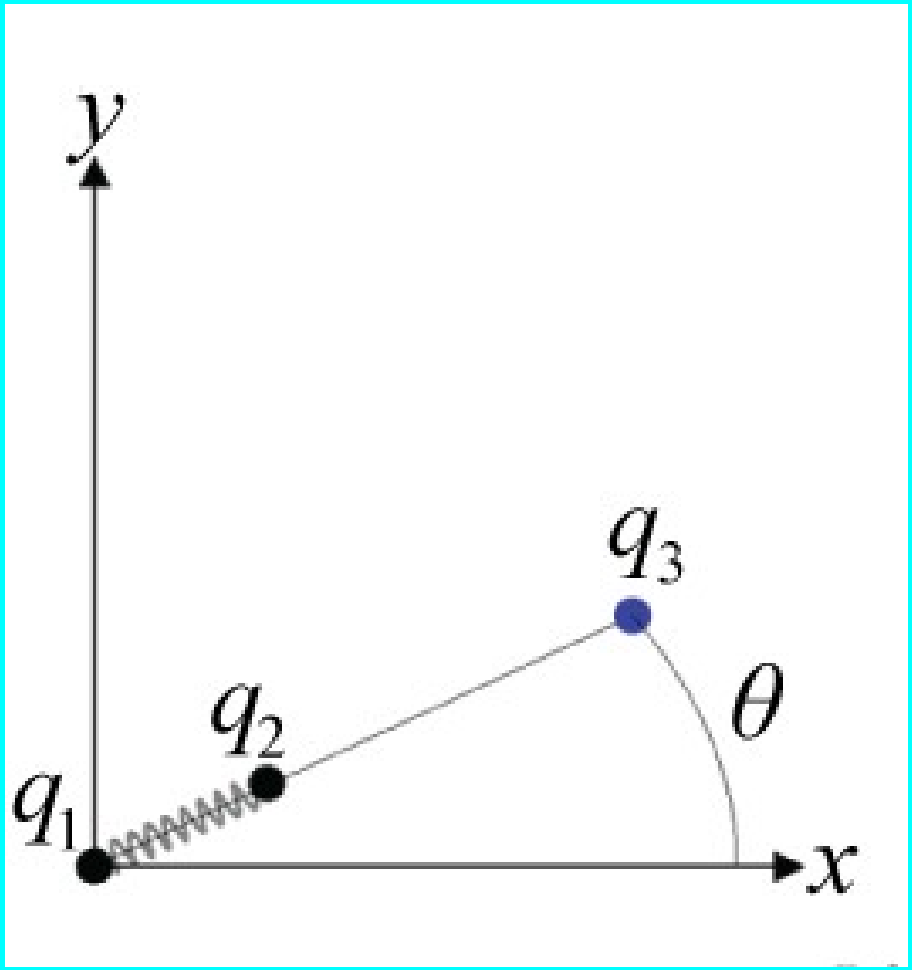
$$F = k\frac{q_1 q_2}{r^2}$$

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

Online Problem 2-9

$q_1 = q_2 = q \quad q_3 = -q$

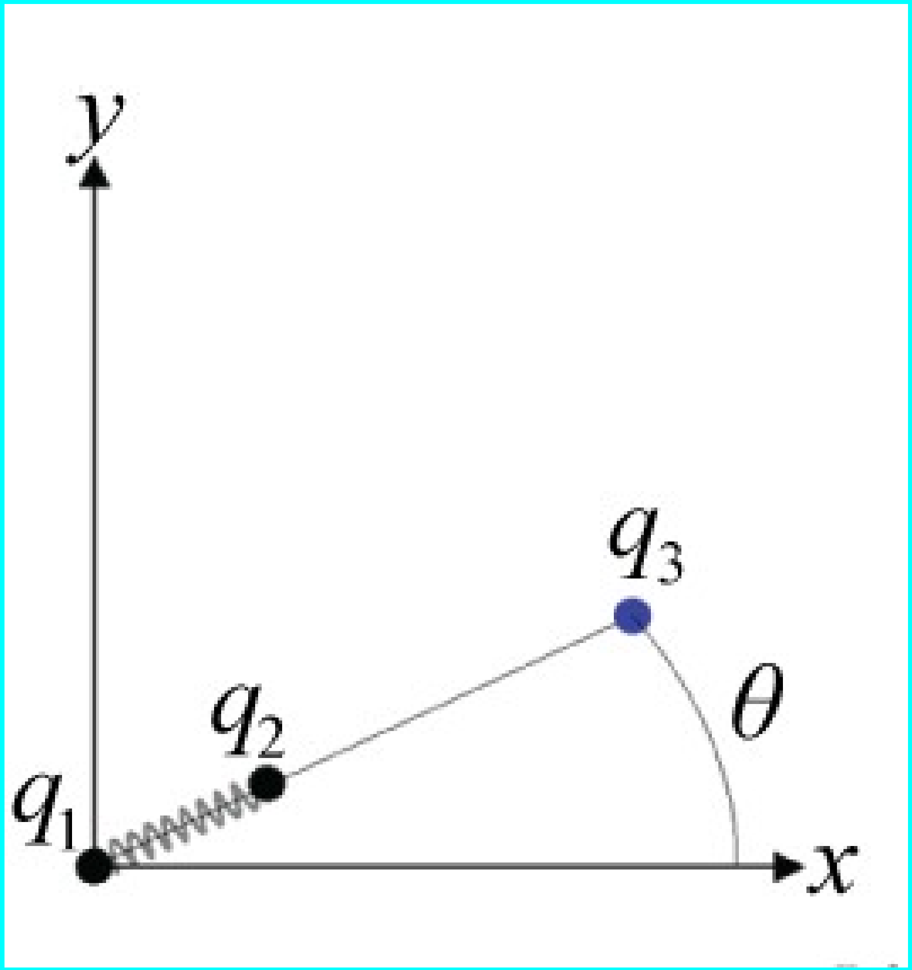
Force on q_2?



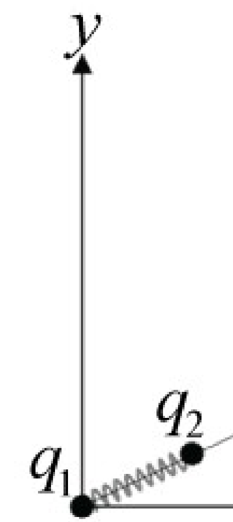
Online Problem 2-9

$q_1 = q_2 = q \quad q_3 = -q$

Force on q_2?



Problem 9: Three charged particles lie in the xy plane at an angle of θ relative to the x-axis. Charge q_1 is located at the origin, q_2 is a distance r from q_1, and q_3 is a distance $3r$ from q_1. The charges each have magnitude of q, but $q_1 = q_2 = +q$, and $q_3 = -q$. Charges q_1 and q_3 are fixed, and q_2 can move. However, q_1 and q_2 are connected by an ideal, neutral spring of spring constant k_s. The spring is initially not stretched. Let Coulomb's constant be k_e. q_1 and q_2 are positive and q_3 is negative.



Part (a) Choose the best expression for the net electrostatic force on q_2, in terms of the given variables.

Expression :

F = ____

Select from the variables below to write your expression. Note that all variables may not be required.

cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), γ, (,), i, j, k_e, n, q, r

Part (b) Because the force on q_2 is nonzero, it will begin to move from rest. In which direction will it move?

MultipleChoice :

1) It will move toward q_3.
2) It will not move.
3) There is not enough information.
4) It will move out of the xy plane.
5) It will move toward q_1.
6) It will move along the $+x$ direction.
7) It will move along the $+y$ direction.

Part (c) When q_2 begins to move, it will stretch the spring. Choose the equation for the force vector from the spring, $\mathbf{F}_s$, due to stretching the spring a dis

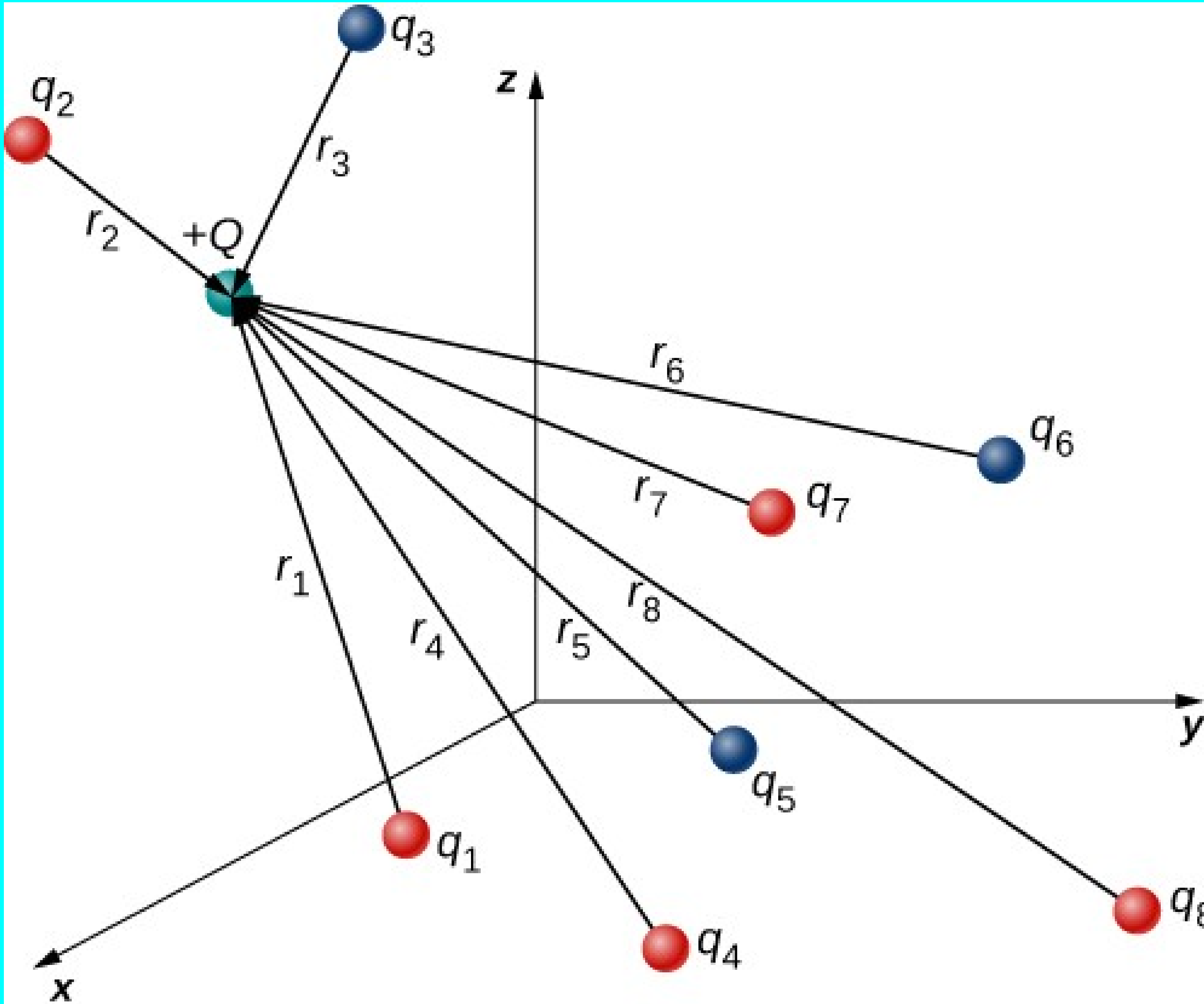
Coulomb's Law, Vector Form

$$\vec{F}_{12} = k\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$$

$$\vec{F}_{net} = \sum_{n=1}^{N} k\frac{q_1 q_n}{r_{1n}^2}\hat{r}_{1n}$$

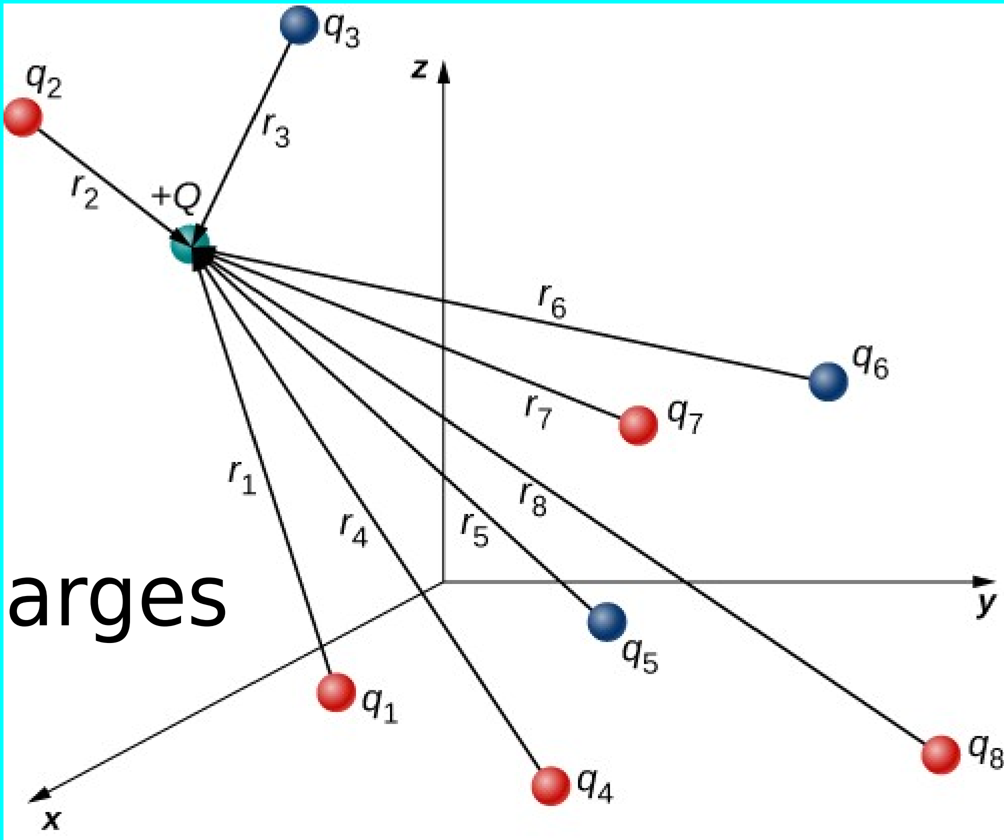
$$\vec{F}_{net} = Q\sum_{n=1}^{N} k\frac{q_n}{r_n^2}\hat{r}_n$$

$\hat{r}$



Making friends with “r-hat”

$\hat{r}$

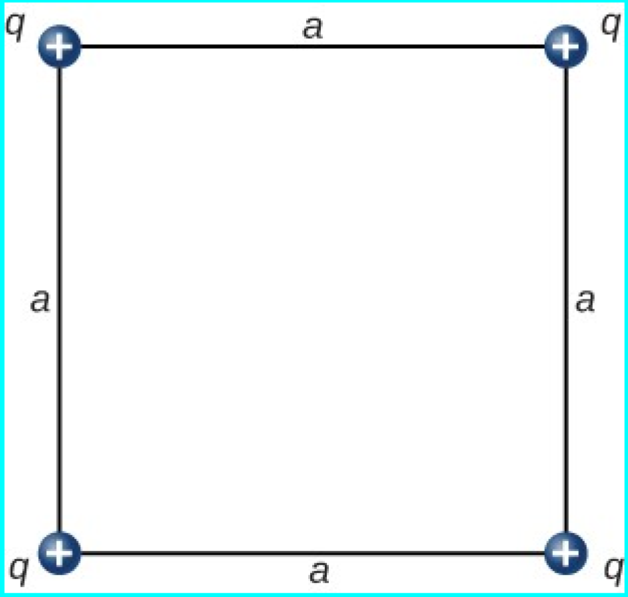


r-hat points from other charges to 'your' charge.

$\hat{r}$ is a unit vector like $\hat{i}, \hat{j},$ and $\hat{k}$

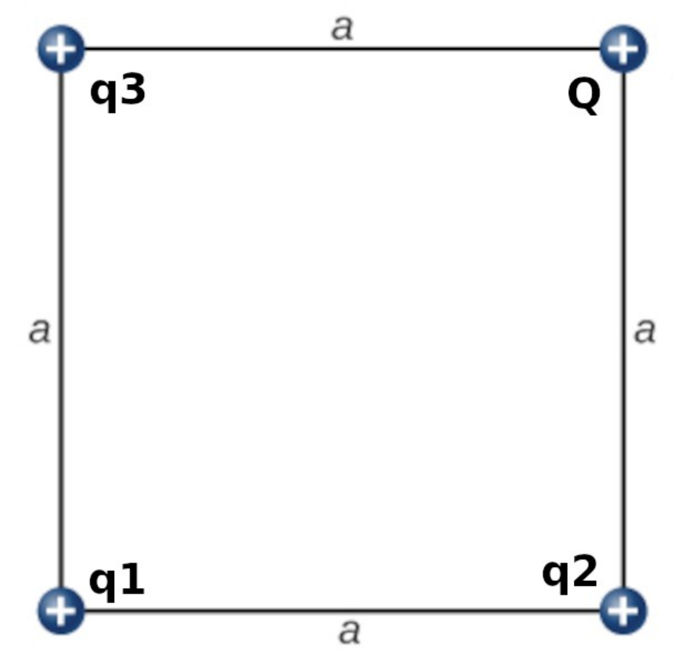
$\hat{r}$ points in different directions for different charges

Homework 5-63-ish

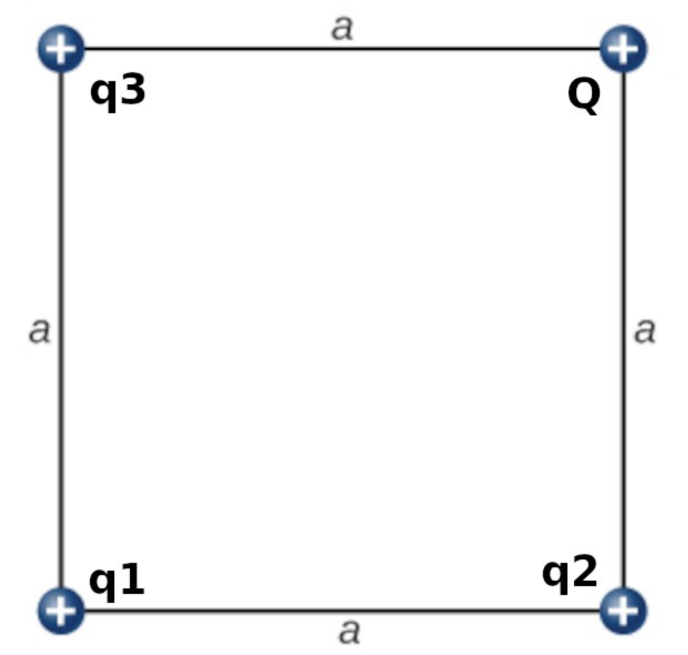


Find force on the q on top right corner

$$\overrightarrow{F_{net}} = Q \sum_{n=1}^{N} k \frac{q_n}{r_n^2} \hat{r}_n$$

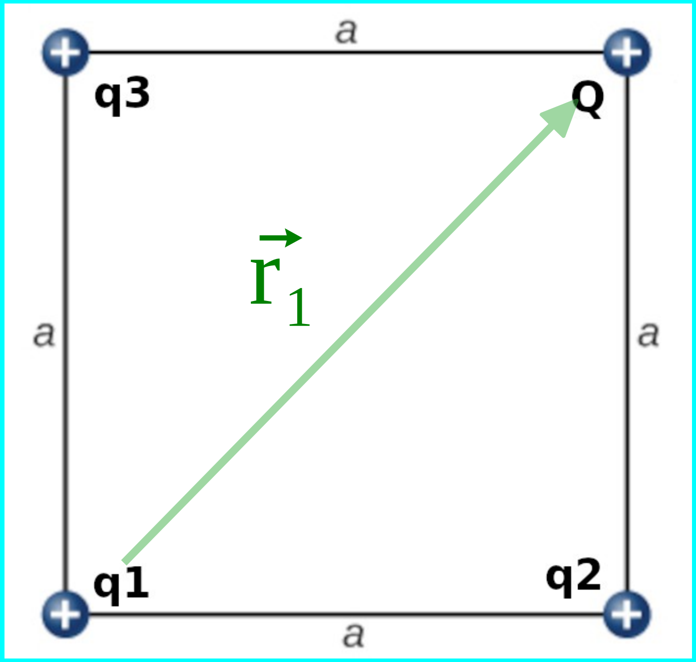


$$\vec{F}_{net} = Q \sum_{n=1}^{N} k \frac{q_n}{r_n^2} \hat{r}_n$$



$$\vec{F}_{net} = Q \sum_{n=1}^{N} k \frac{q_n}{r_n^2} \hat{r}_n$$

What is r_1^2?



(A) $\frac{\sqrt{2}}{2}a$

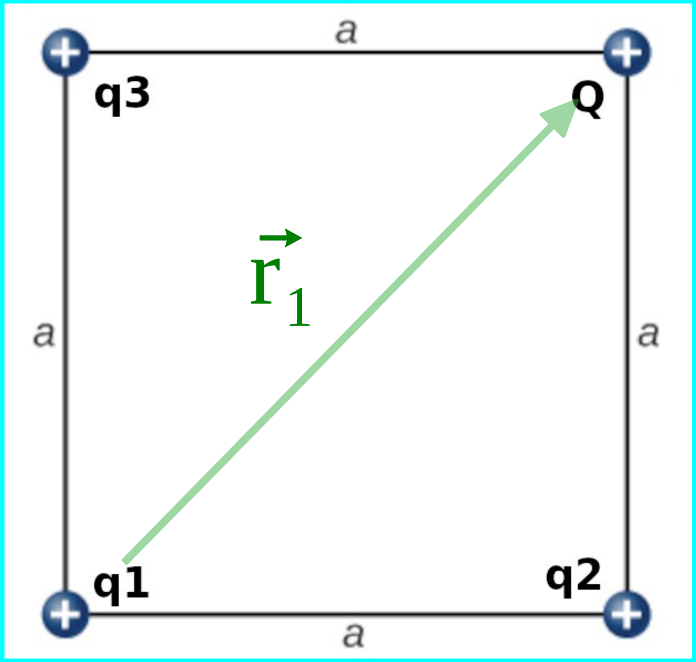
(B) $\sqrt{2}a$

(C) $\sqrt{2}a^2$

(D) $2a$

(E) $2a^2$

What is $\vec{r}_1$?



(A) a

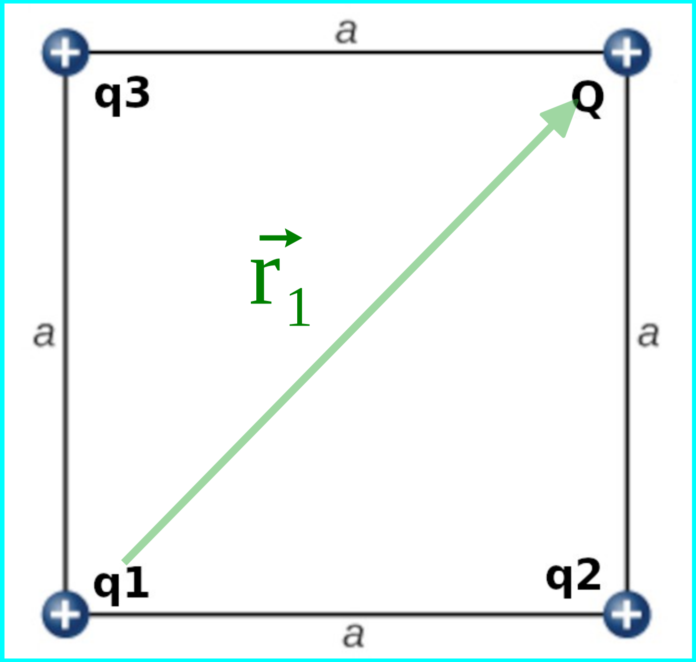
(B) $a\hat{i}$

(C) $a\hat{i}+a\hat{j}$

(D) $\sqrt{2}a\hat{i}+\sqrt{2}a\hat{j}$

(E) $\frac{\sqrt{2}}{2}a\hat{i}+\frac{\sqrt{2}}{2}a\hat{j}$

What is $\hat{r}_1$?



(A) a

(B) $\hat{i}$

(C) $\hat{i}+\hat{j}$

(D) $\sqrt{2}\,\hat{i}+\sqrt{2}\,\hat{j}$

(E) $\dfrac{\sqrt{2}}{2}\hat{i}+\dfrac{\sqrt{2}}{2}\hat{j}$

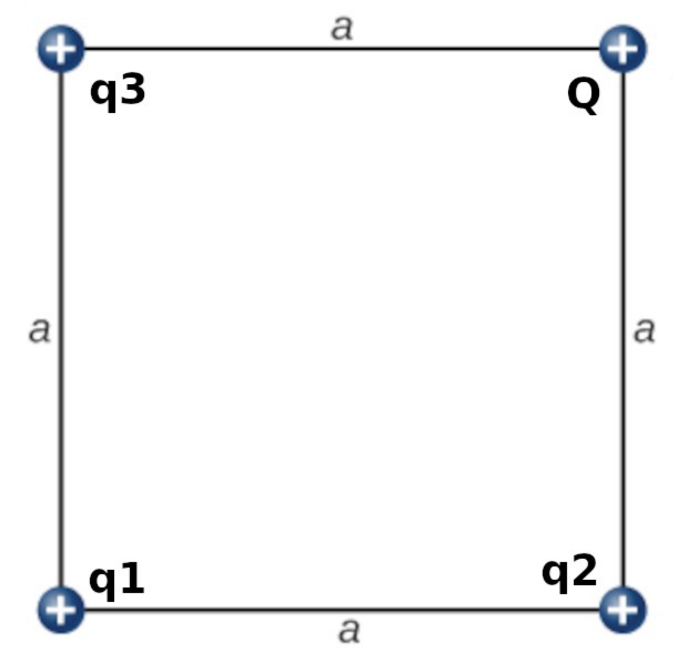
From Coulomb's Law to Electric field

$$\overrightarrow{F_{net}} = Q \sum_{n=1}^{N} k \frac{q_n}{r_n^2} \hat{r}_n$$

$$\vec{E} = \sum_{n=1}^{N} k \frac{q_n}{r_n^2} \hat{r}_n$$

$$\overrightarrow{F_{net}} = Q \vec{E}$$

Homework 5-63-ish with field



Find $\vec{E}$-field at top right corner in absence of Q

Superposition (Force)

The net force on $-Q$ is

A. Up.

B. Down.

C. Left.

D. Right.

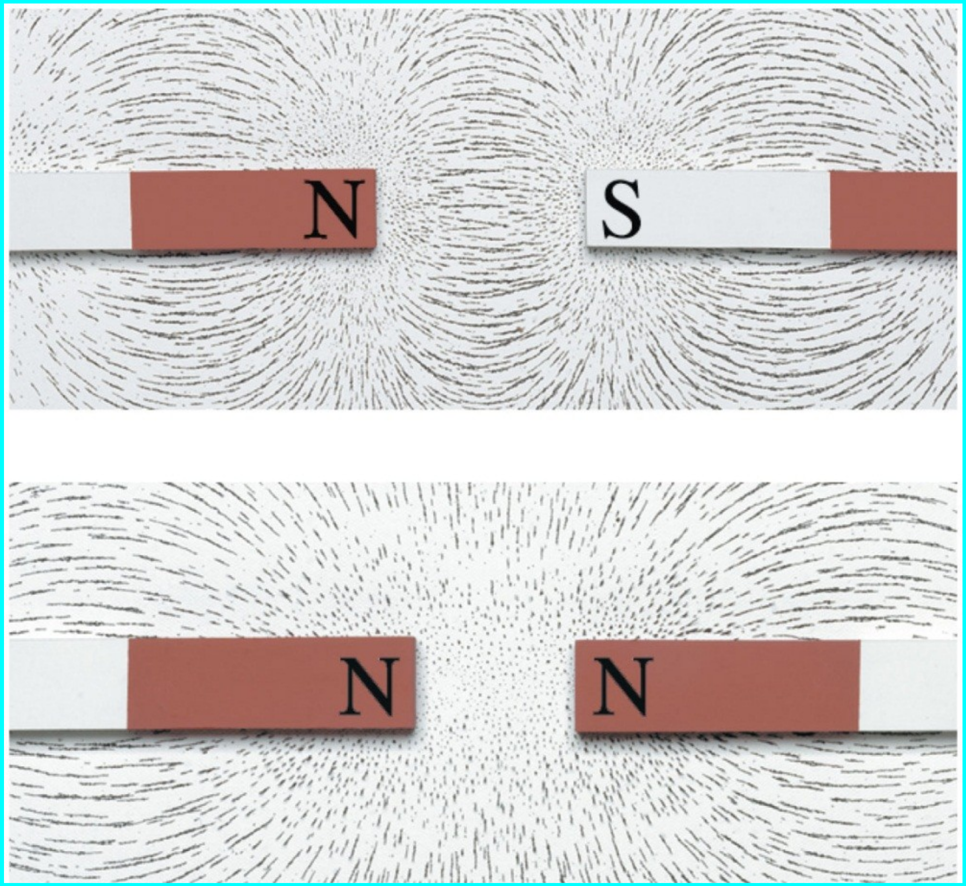
E. The force on $-q$ is zero.

Superposition (Field)

The net field at the position "P" is

A. Up.
B. Down.
C. Left.
D. Right.
E. The force on $-q$ is zero.

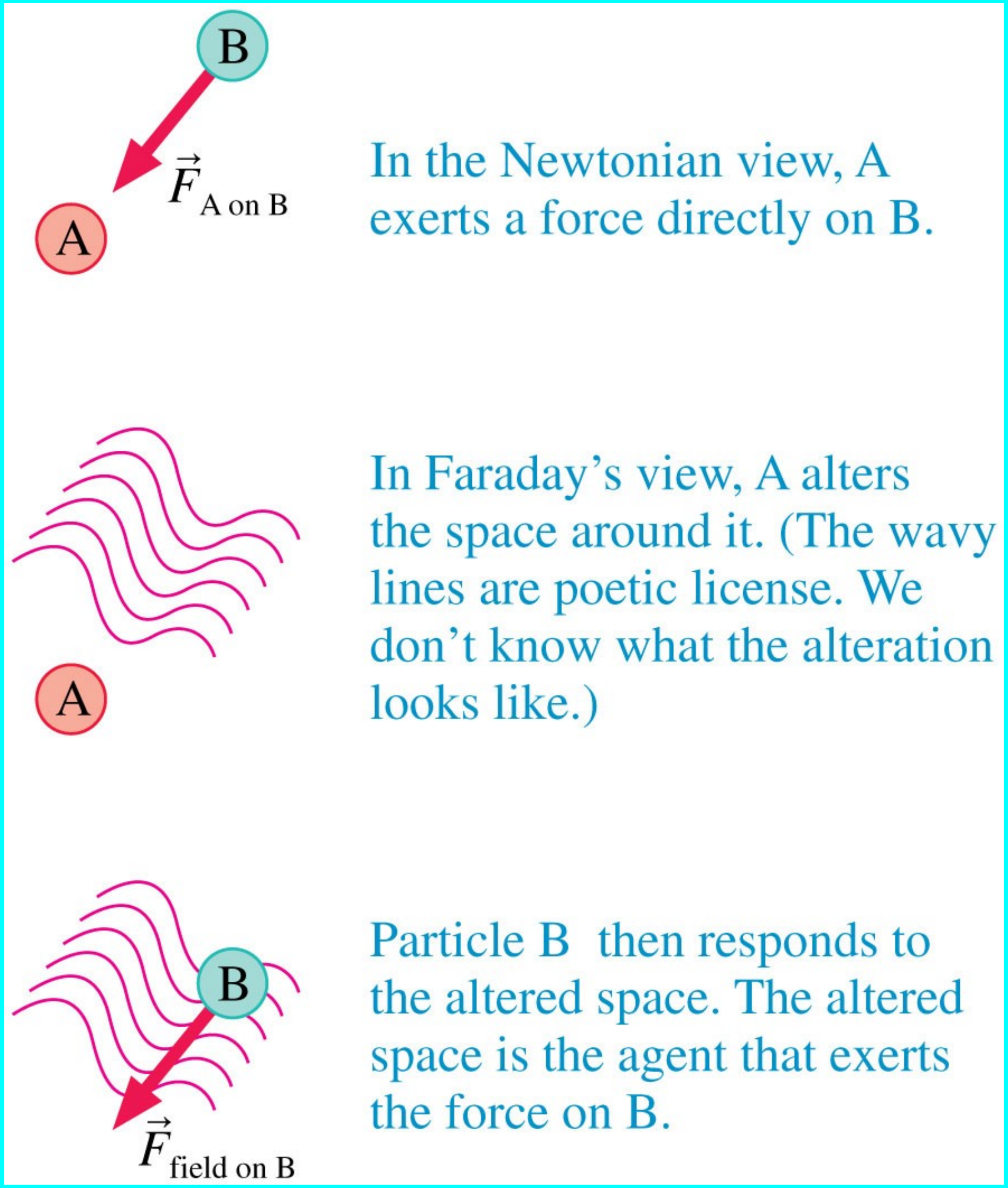
The Field Model



- The photos show the patterns that iron filings make when sprinkled around a magnet.
- These patterns suggest that *space itself* around the magnet is filled with magnetic influence.
- This is called the **magnetic field**.
- The concept of such a “field” was first introduced by Michael Faraday in 1821.

The Field Model

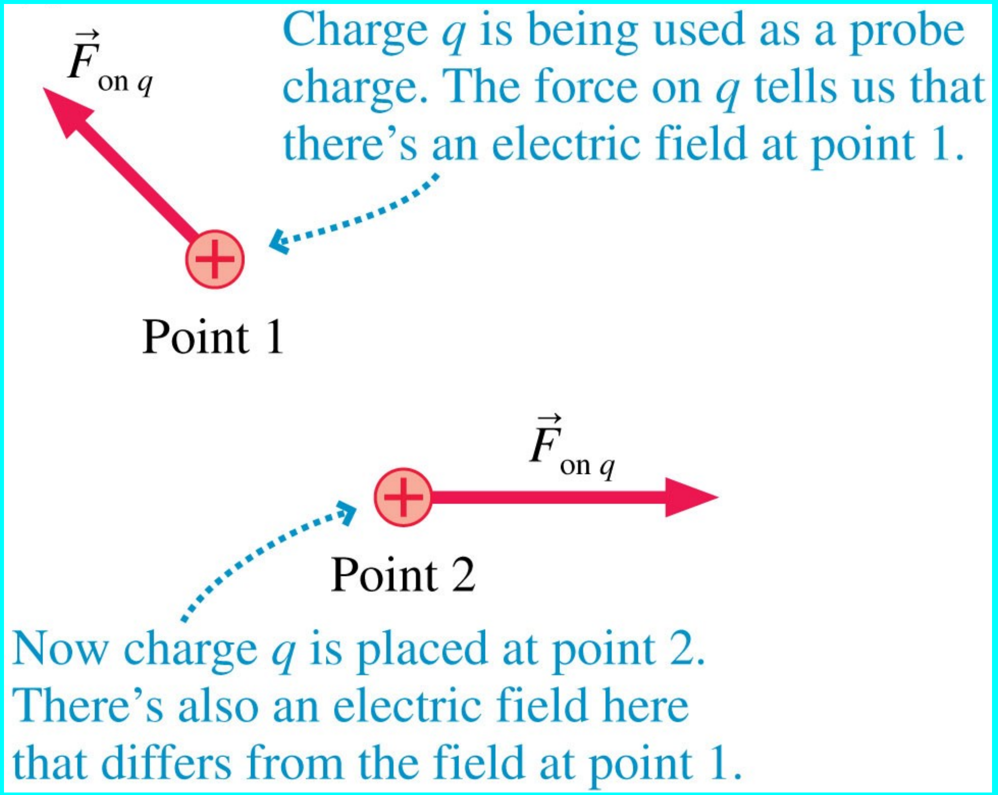
- A *field* is a function that assigns a vector to every point in space.
- The alteration of space around a mass is called the *gravitational field*.
- Similarly, the space around a charge is altered to create the **electric field**.



The Electric Field

- If a probe charge (or test charge) “q” experiences an electric force at a point in space, we say that there is an electric field $\vec{E}$ at that point causing the force.

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

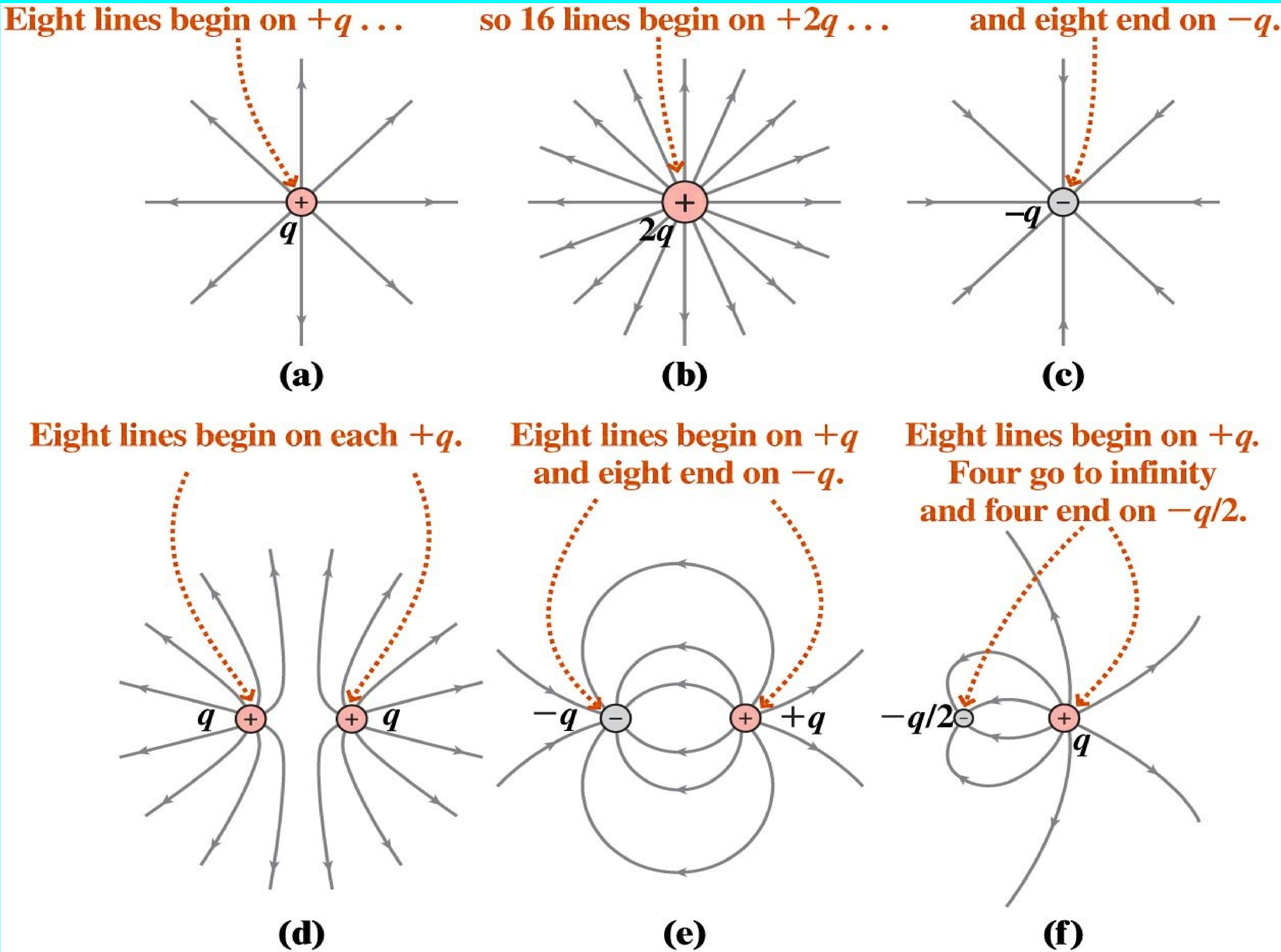


The units of the electric field are N/C. The magnitude E of the electric field is called the **electric field strength.**

Electric Field Lines

- A way of getting intuition for the fields caused by a few charges (without calculating)

- Positive charges "emit" field lines.
- Negative charges "absorb" field lines.
- Field lines begin at + charge and end at infinity or negative charge.
- The tangent to an electric field line gives direction of force
- Electric field lines do not cross



Eight lines begin on +q . . .
q
(a)
so 16 lines begin on +2q . . .
2q
(b)
and eight end on −q.
−q
(c)
Eight lines begin on each +q.
q
q
(d)
Eight lines begin on +q
and eight end on −q.
−q
+q
(e)
Eight lines begin on +q.
Four go to infinity
and four end on −q/2.
−q/2
q
(f)

Key Equations

Coulomb's law	$\vec{\mathbf{F}}_{12}(r) = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{12}^2} \hat{\mathbf{r}}_{12}$
Superposition of electric forces	$\vec{\mathbf{F}}(r) = \frac{1}{4\pi\varepsilon_0} Q \sum_{i=1}^{N} \frac{q_i}{r_i^2} \hat{\mathbf{r}}_i$
Electric force due to an electric field	$\vec{\mathbf{F}} = Q\vec{\mathbf{E}}$
Electric field at point P	$\vec{\mathbf{E}}(P) \equiv \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{N} \frac{q_i}{r_i^2} \hat{\mathbf{r}}_i$
Field of an infinite wire	$\vec{\mathbf{E}}(z) = \frac{1}{4\pi\varepsilon_0} \frac{2\lambda}{z} \hat{\mathbf{k}}$
Field of an infinite plane	$\vec{\mathbf{E}} = \frac{\sigma}{2\varepsilon_0} \hat{\mathbf{k}}$
Dipole moment	$\vec{\mathbf{p}} = q\vec{\mathbf{d}}$

Next Class:

Electric field and flux