Lecture 06: 02/01/2024

- Announcements
  Calendly works for office hours

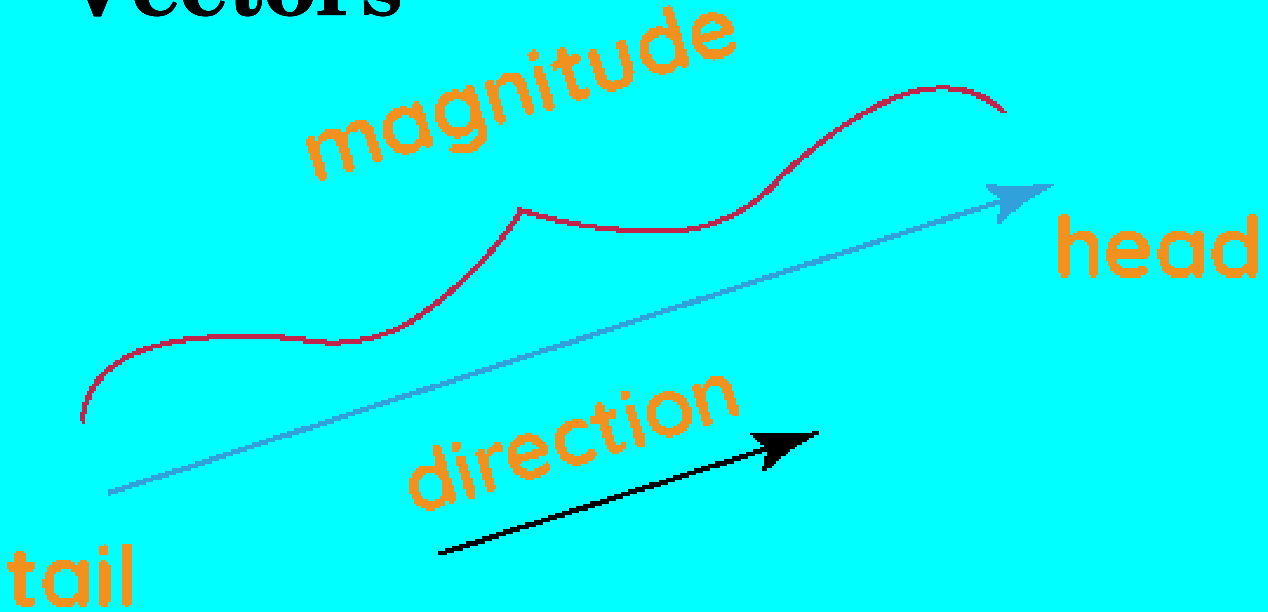
- Last Time
  - Coulomb's Law
    Coulomb vector form and r-hat
    Electric field
    Electric field lines

- Today
  Electric field
  More examples of vector addition for electric field
  Electric field lines

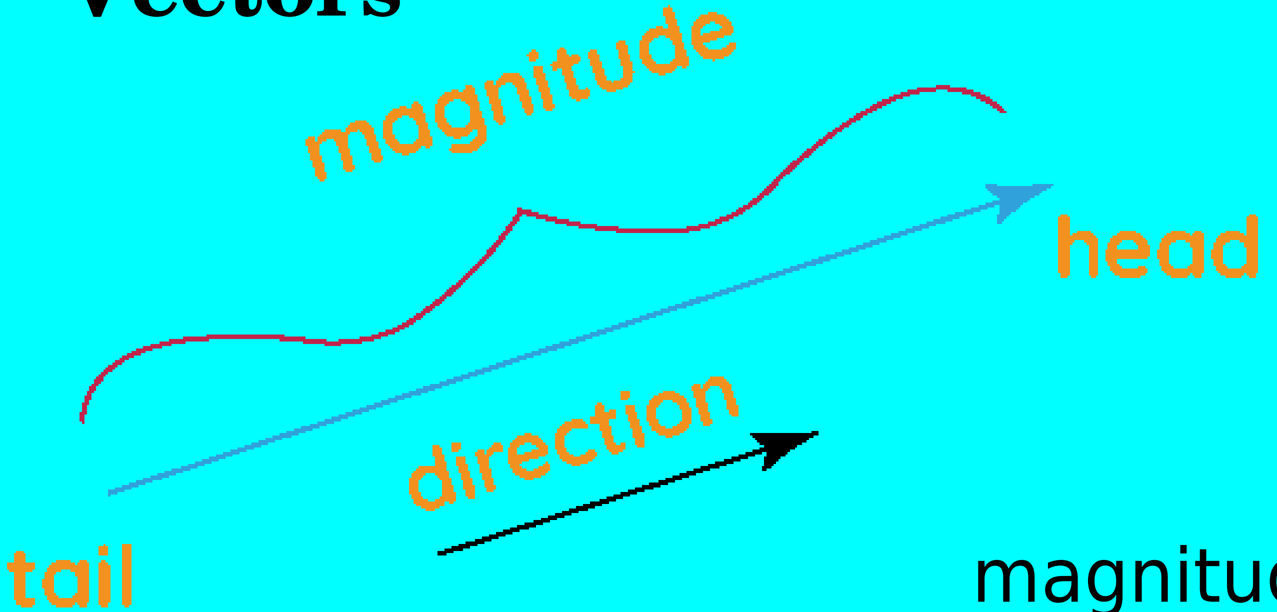
SCHEDULE

#	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	

Vectors



Vectors



magnitude=length

'unit' vector has length one

unit vector has a 'hat'

Electric field and gravitational field

Electric field and gravitational field

$$\vec{F} = M \frac{G m_{earth}}{r^2} \hat{r}$$

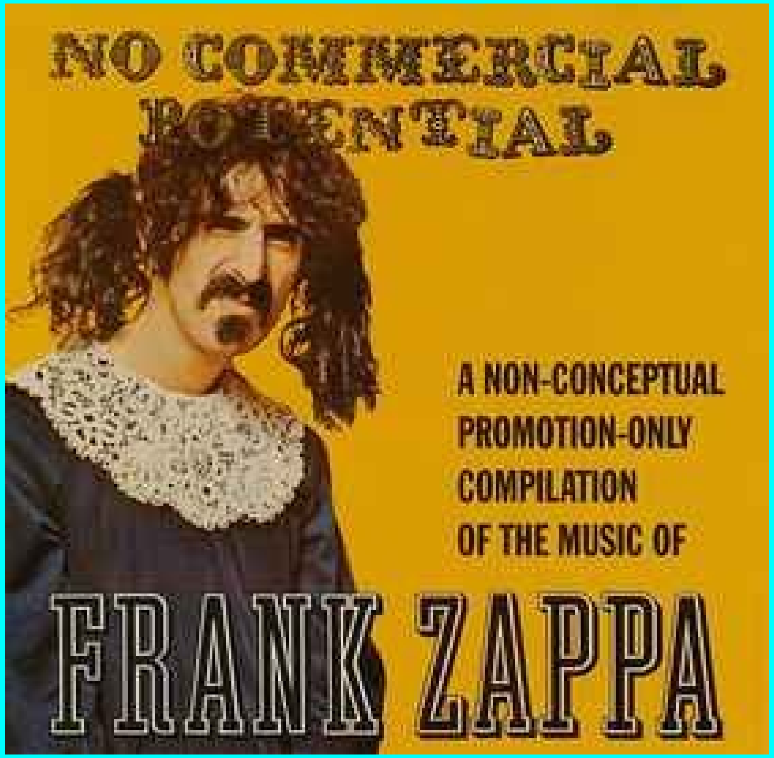
$$\vec{F} = Q \frac{k q_{electron}}{r^2} \hat{r}$$

$$\vec{g} = \frac{G m_{earth}}{r^2} \hat{r}$$

$$\vec{E} = \frac{k q_{electron}}{r^2} \hat{r}$$

$$\vec{F} = M \vec{g}$$

$$\vec{F} = Q \vec{E}$$


NO COMMERCIAL POTENTIAL
A NON-CONCEPTUAL
PROMOTION-ONLY
COMPILATION
OF THE MUSIC OF
FRANK ZAPPA


STRICTLY COMMERCIAL
FRANK THE BEST OF ZAPPA

Two body gravitational force

M_{zappa}

Two body gravitational field

Two body electric force

Q_{zappa}

Two body electric field

Coulomb's Law and Gravitation

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

$$F_G = G\frac{m_1 m_2}{r^2}$$

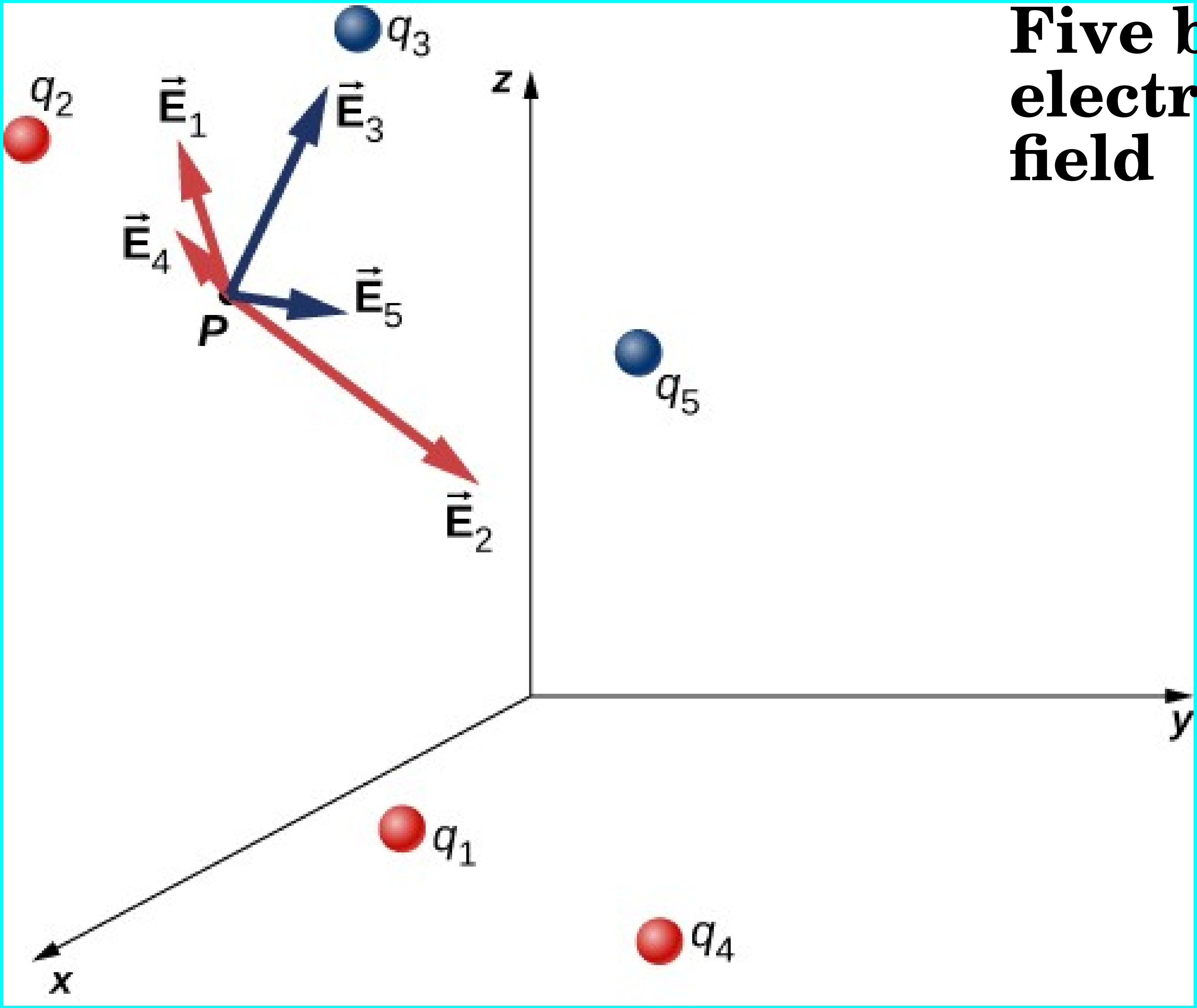
$$k = 8.99 \times 10^9 \frac{N\,m^2}{C^2}$$

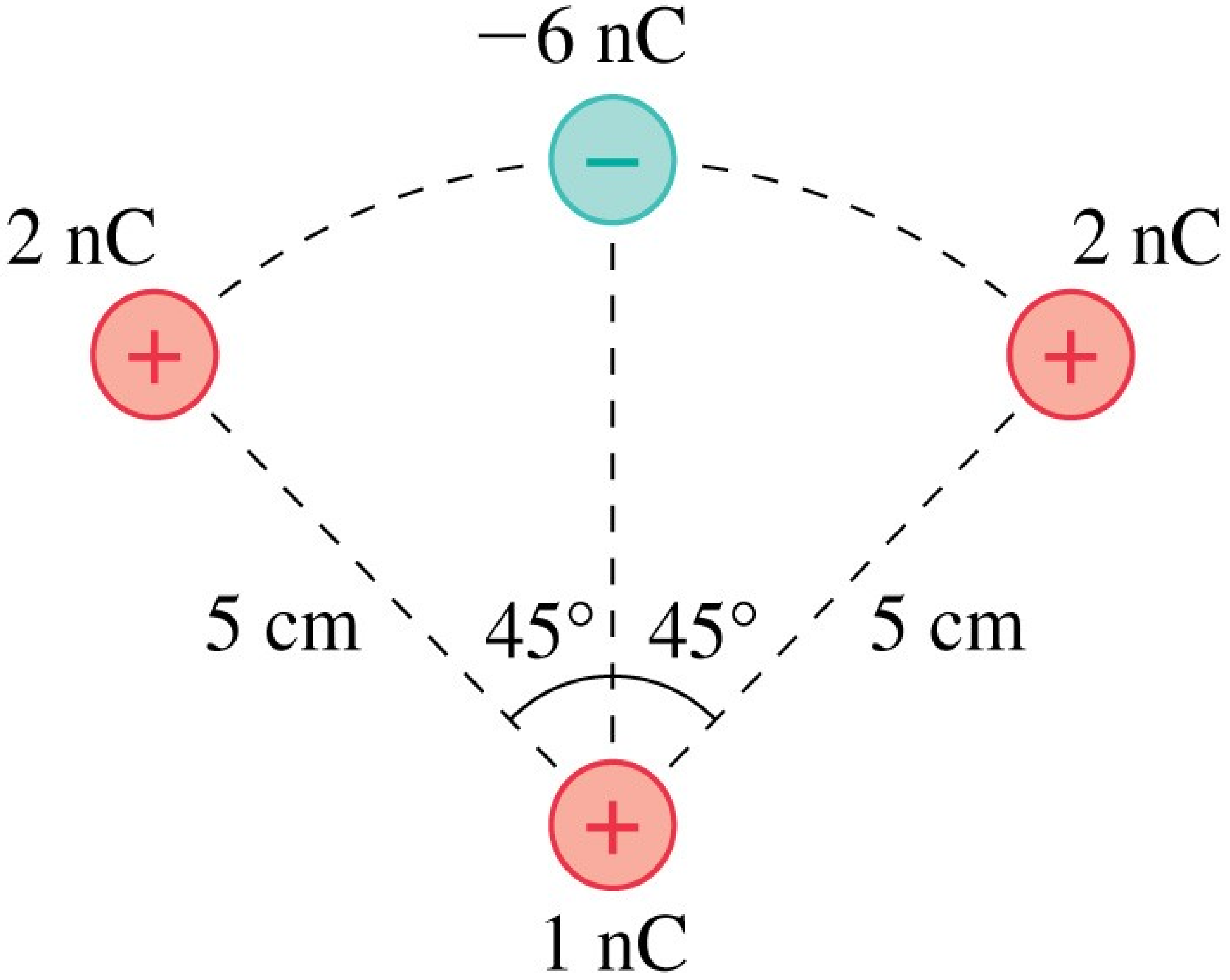
$$G = 6.674 \times 10^{-11} N\,m^2/kg^2$$

Why do masses attract?

Why do charges attract/repel?

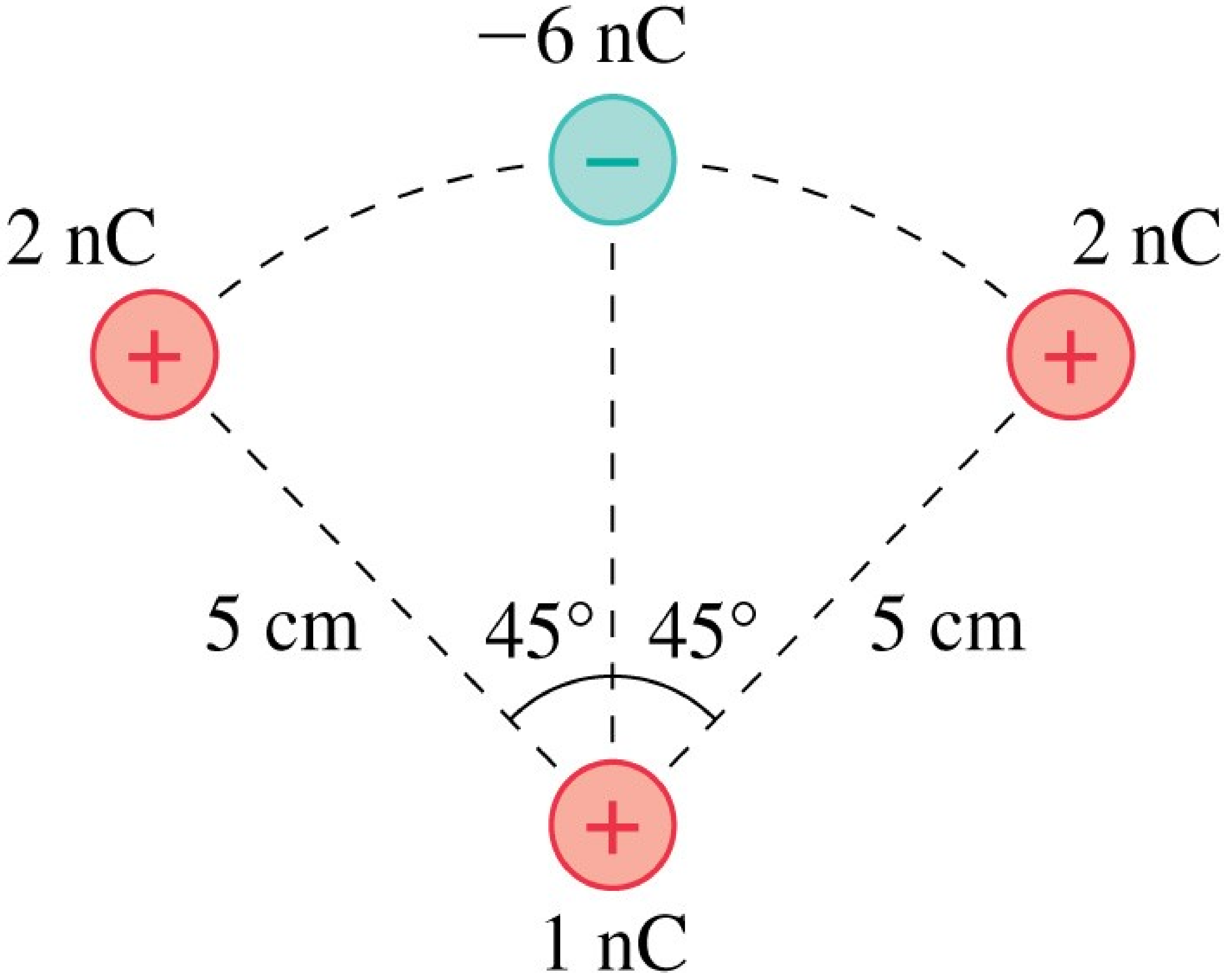
Five body electric field

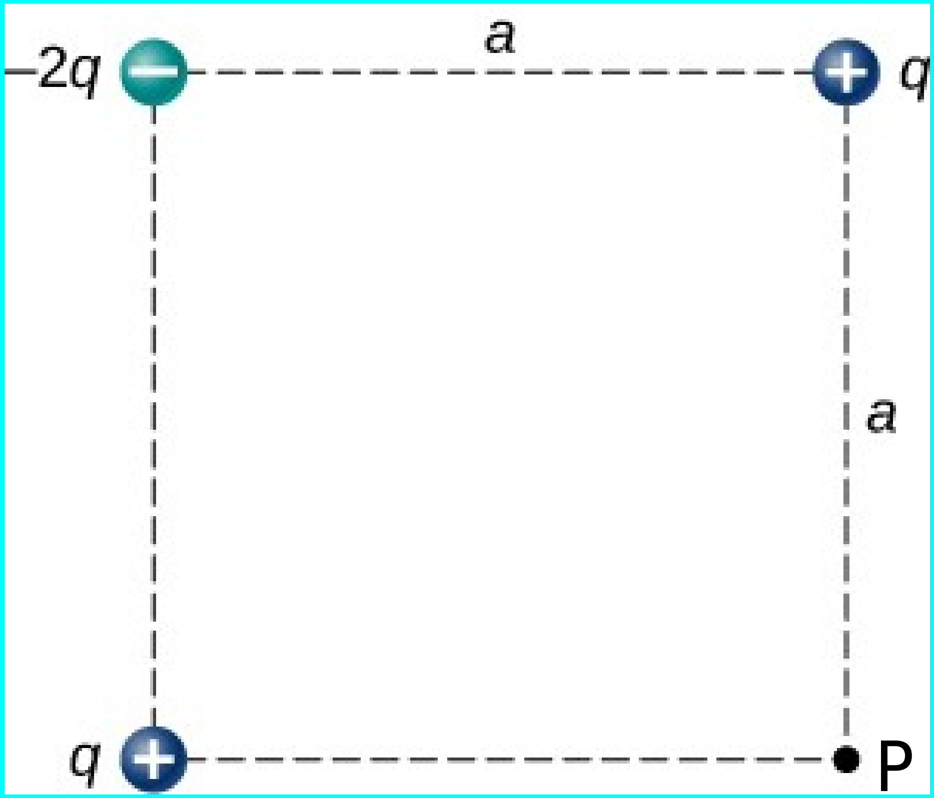




What is the direction of the field at the 1 nC charge?

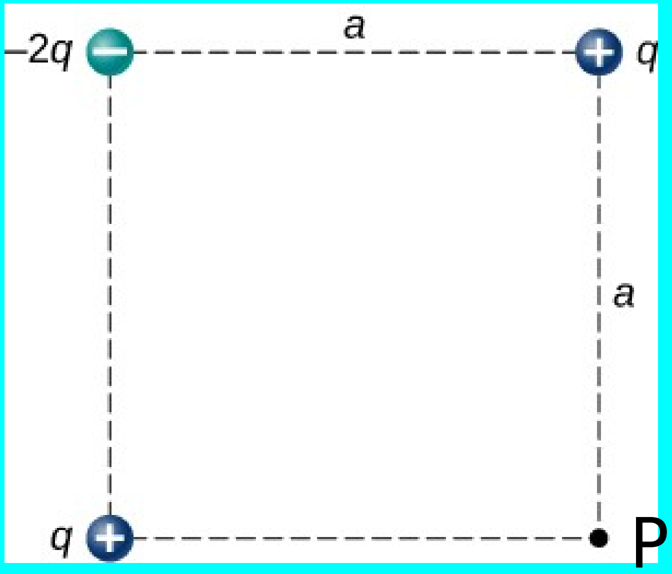
Is it
(A) Up
(B) Down
(C) Zero
(D) Left
(E) Right


−6 nC
2 nC
2 nC
5 cm
45°
45°
5 cm
1 nC



$q = 1\,\mu C \qquad a = 3\,m$

$\vec{E}_p$?



$q = 1\,\mu C \quad a = 3\,m$

What is $\vec{E}_2$?

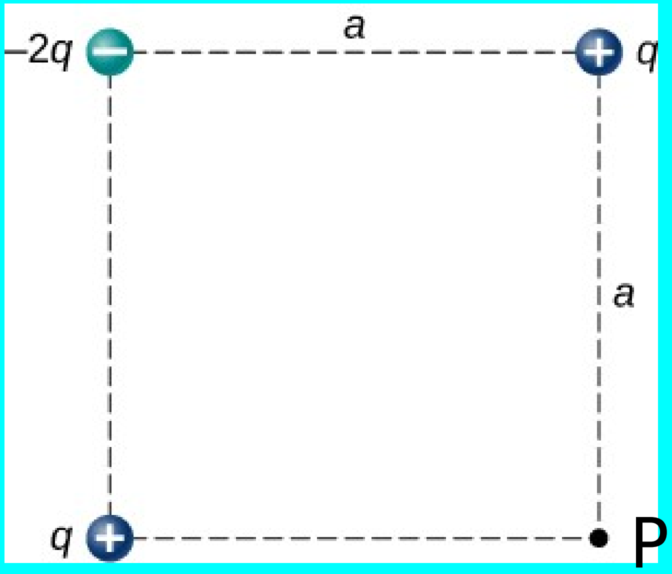
(**A**) $1000\,\hat{i}$ N/C

(**B**) $3000\,\hat{j}$ N/C

(**C**) $1\times10^{9}\,\hat{i}$ N/C

(**D**) $-1\times10^{9}\,\hat{j}$ N/C

(**E**) $-1000\,\hat{j}$ N/C



$q = 1\mu C \quad a = 3m$

What is the magnitude of $\vec{E}_3$?

(A) $1000\ \text{N/C}$

(B) $3000\ \text{N/C}$

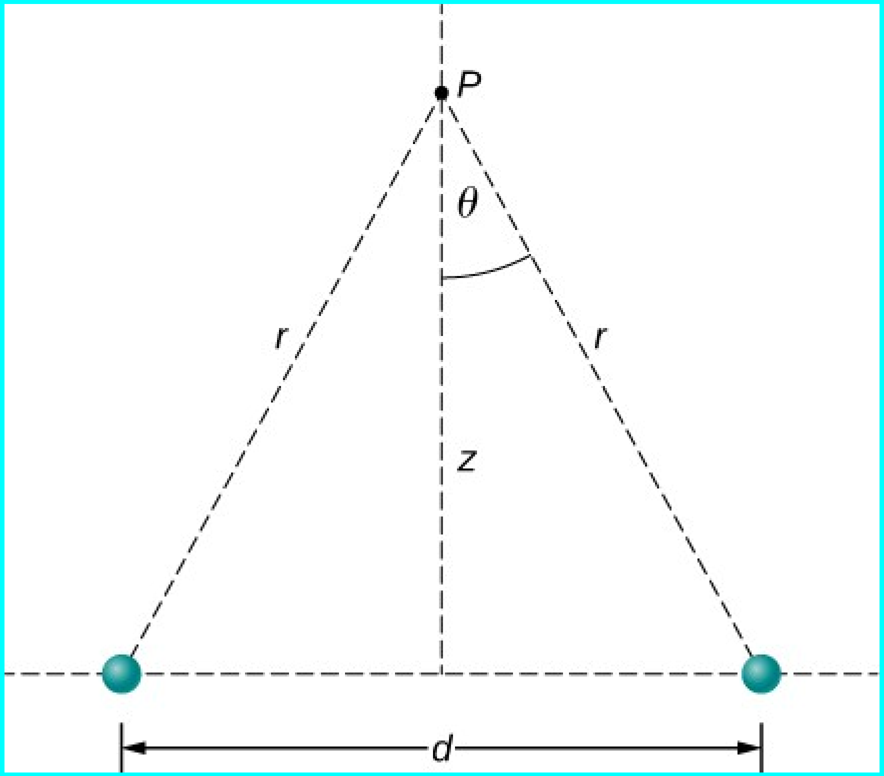
(C) $1 \times 10^9\ \text{N/C}$

(D) $-1 \times 10^9\ \text{N/C}$

(E) $-1000\ \text{N/C}$

$q_1 = q_2 = 5\,nC \qquad d = 10\,cm \qquad \theta = 30^o$

What is the direction of $\vec{E}_P$?



(**A**) Up at an angle

(**B**) Down at an angle

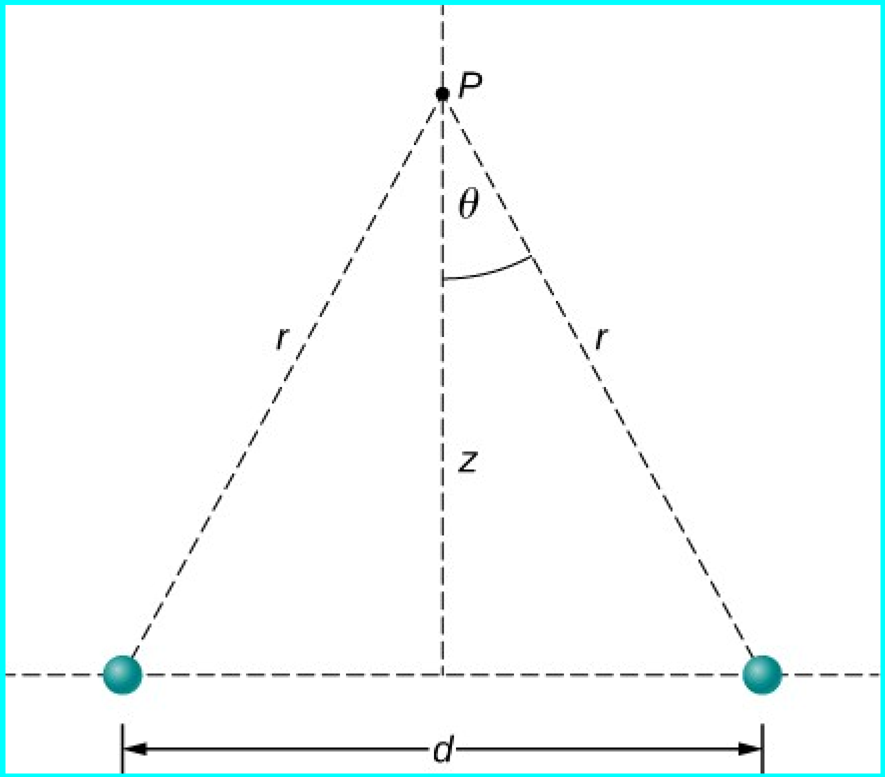
(**C**) Down

(**D**) Up

(**E**) Left

$q_1 = q_2 = 5\,nC \qquad d = 10\,cm \qquad \theta = 30^o$

What is $\vec{E}_P$?



$q_1 = q_2 = 5\,nC \quad d = 10\,cm \quad \theta = 30^o$

$\vec{E}_1 = 3900\,\hat{i} + 2250\,\hat{j}$

What is $\vec{E}_2$?

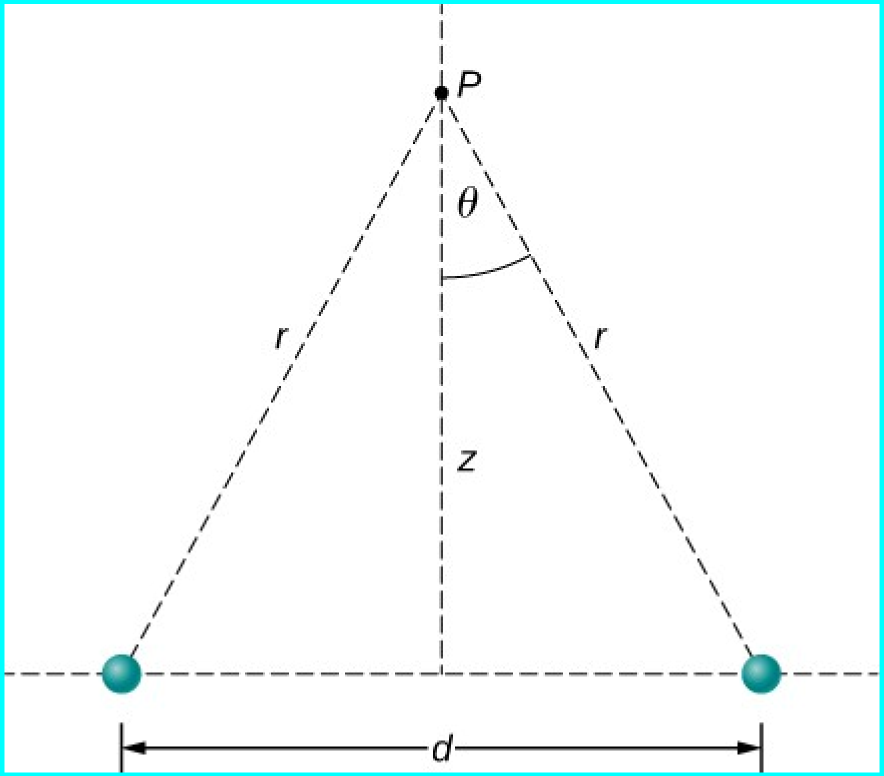
$(\mathbf{A})\quad 2250\,\hat{i} + 3900\,\hat{j}$

$(\mathbf{B})\quad 3900\,\hat{i} + 2250\,\hat{j}$

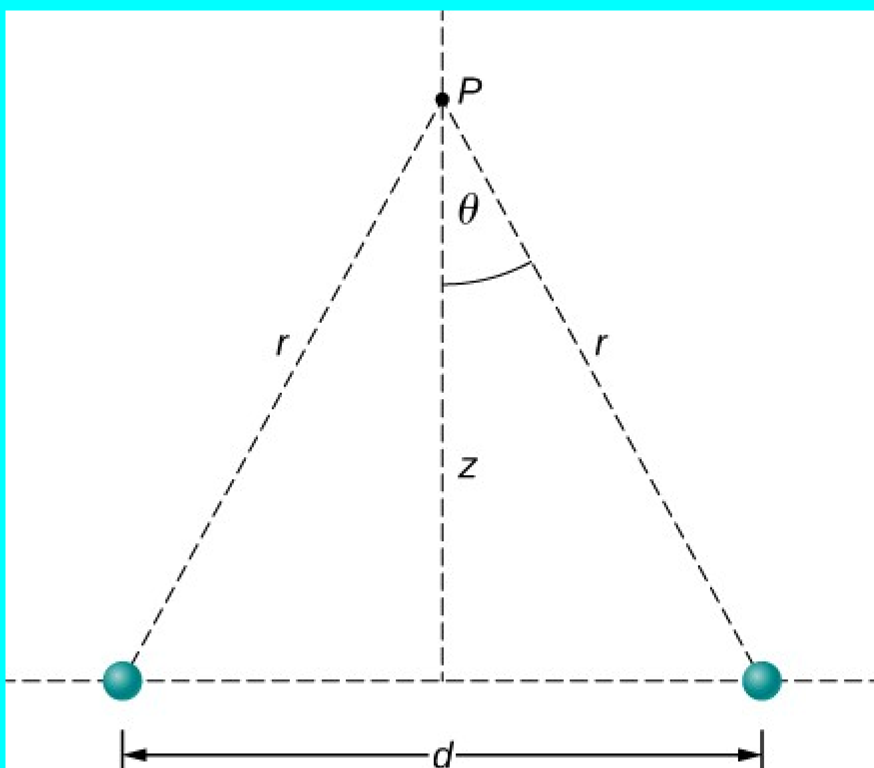
$(\mathbf{C})\quad 3900\,\hat{i} - 2250\,\hat{j}$

$(\mathbf{D})\quad -3900\,\hat{i} - 2250\,\hat{j}$

$(\mathbf{E})\quad -3900\,\hat{i} + 2250\,\hat{j}$



What is the net force on -1 mC placed at P?



$(\mathbf{A})\quad 2.25\,\hat{\mathrm{i}} + 3.90\,\hat{\mathrm{j}}\ \mathrm{N}$

$(\mathbf{B})\quad 3.90\,\hat{\mathrm{i}}\ \mathrm{N}$

$(\mathbf{C})\quad +4500\,\hat{\mathrm{j}}\ \mathrm{N}$

$(\mathbf{D})\quad -4.50\,\hat{\mathrm{j}}\ \mathrm{N}$

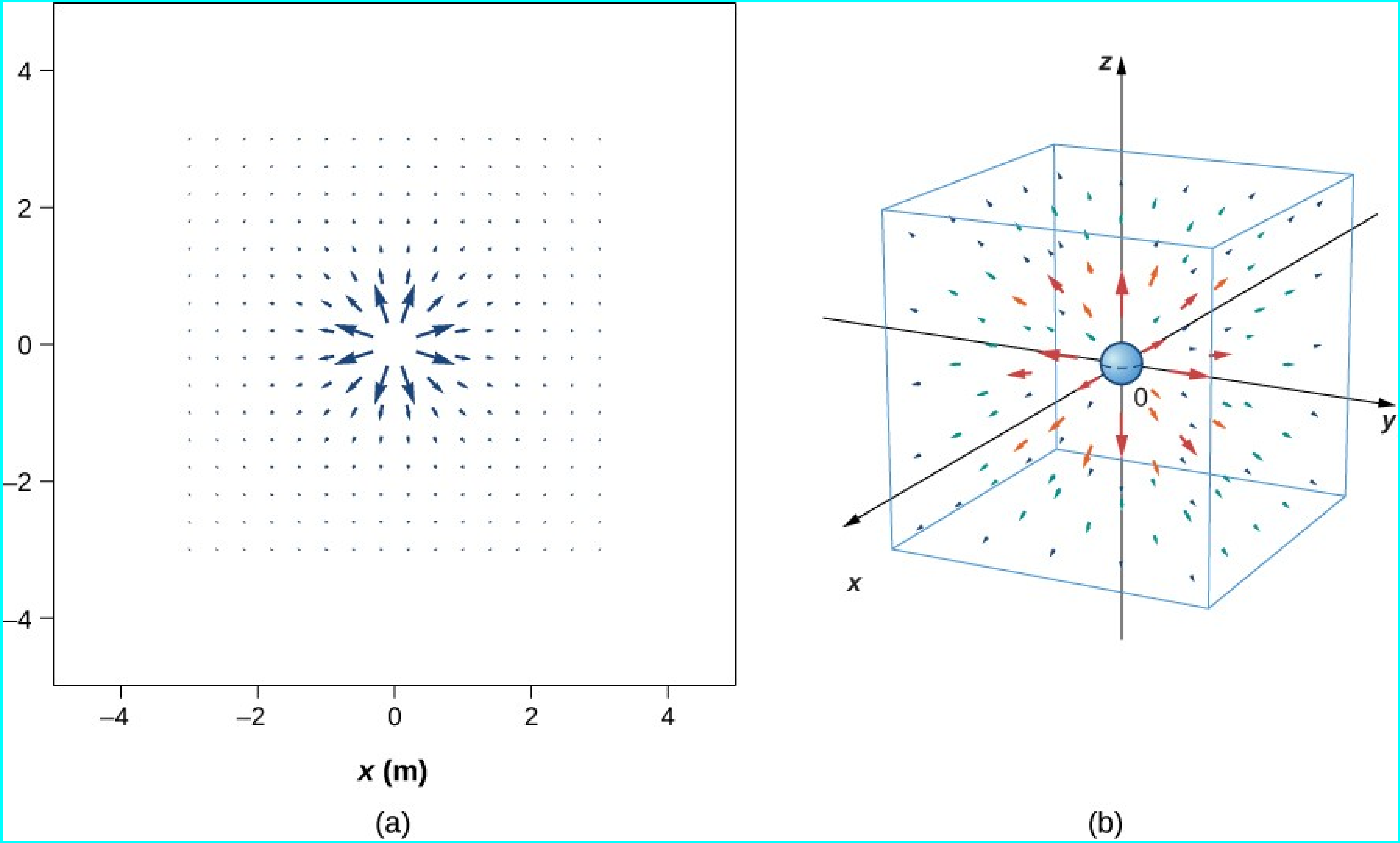
$(\mathbf{E})\quad +4.50\,\hat{\mathrm{j}}\ \mathrm{N}$

Electric Field Lines

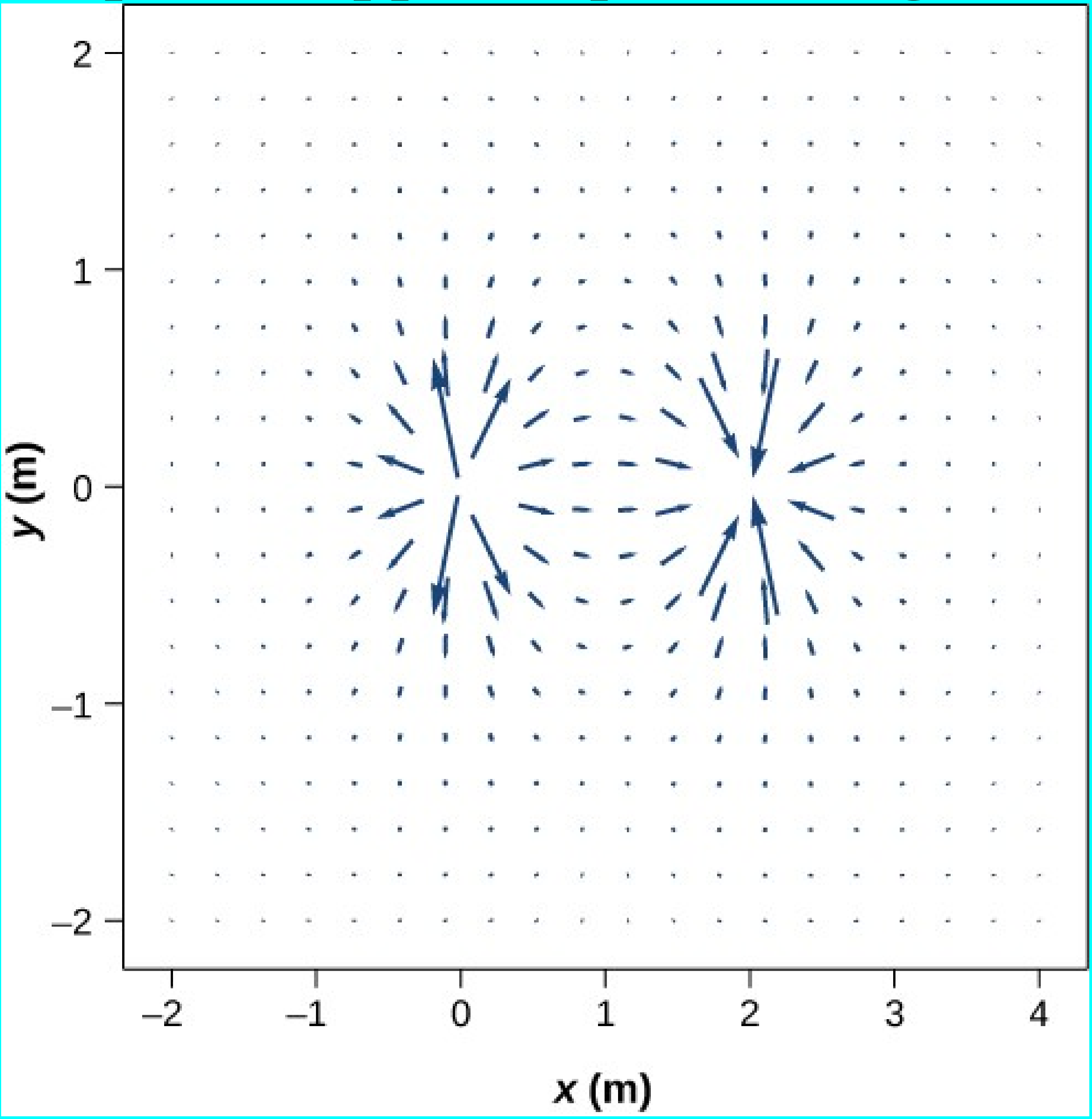
- A way of getting intuition for the fields caused by a few charges (without calculating)

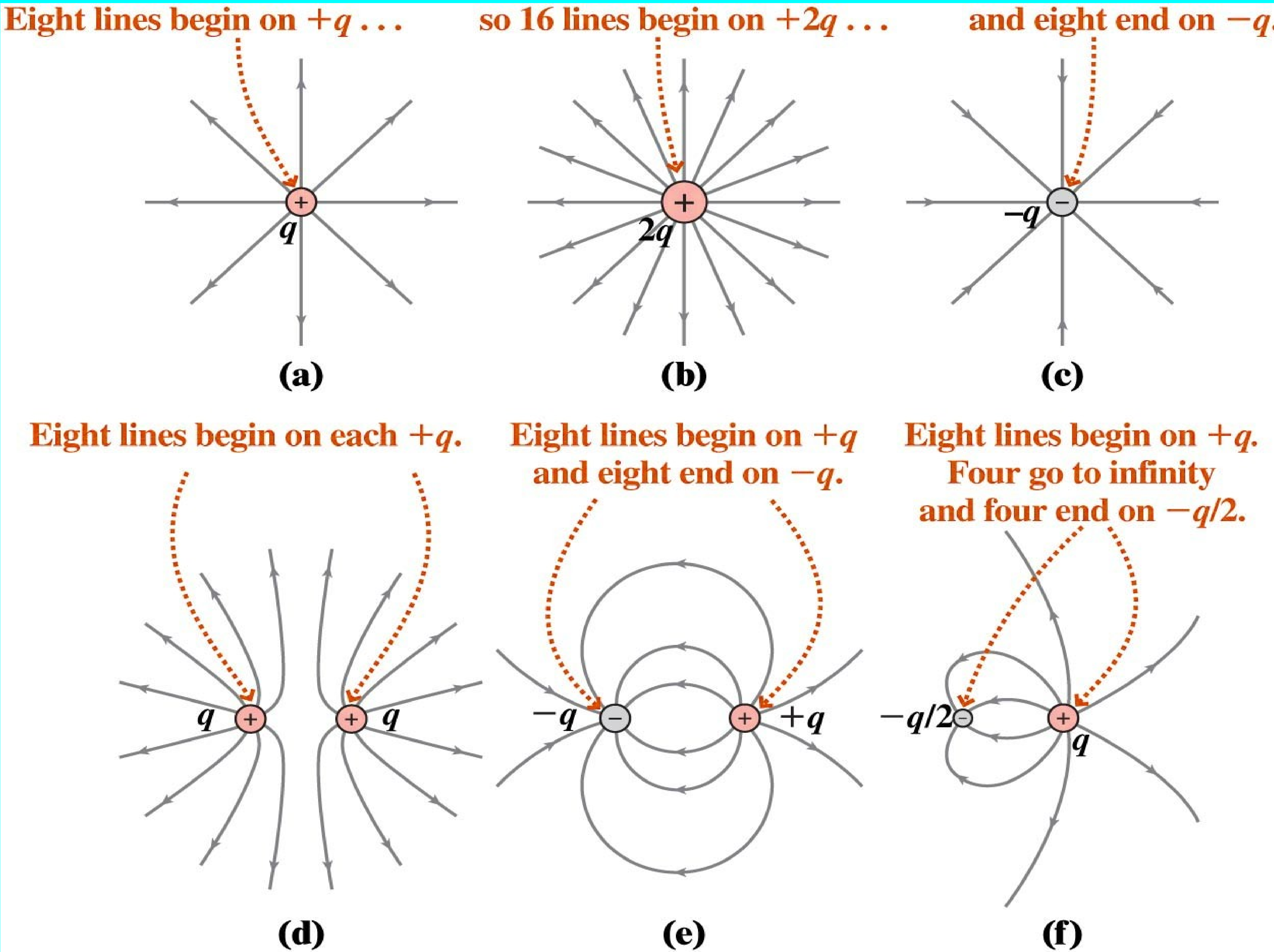
- Positive charges "emit" field lines.
- Negative charges "absorb" field lines.
- Field lines begin at + charge and end at infinity or negative charge.
- The tangent to an electric field line gives direction of force
- Electric field lines do not cross

E-field of a + point charge



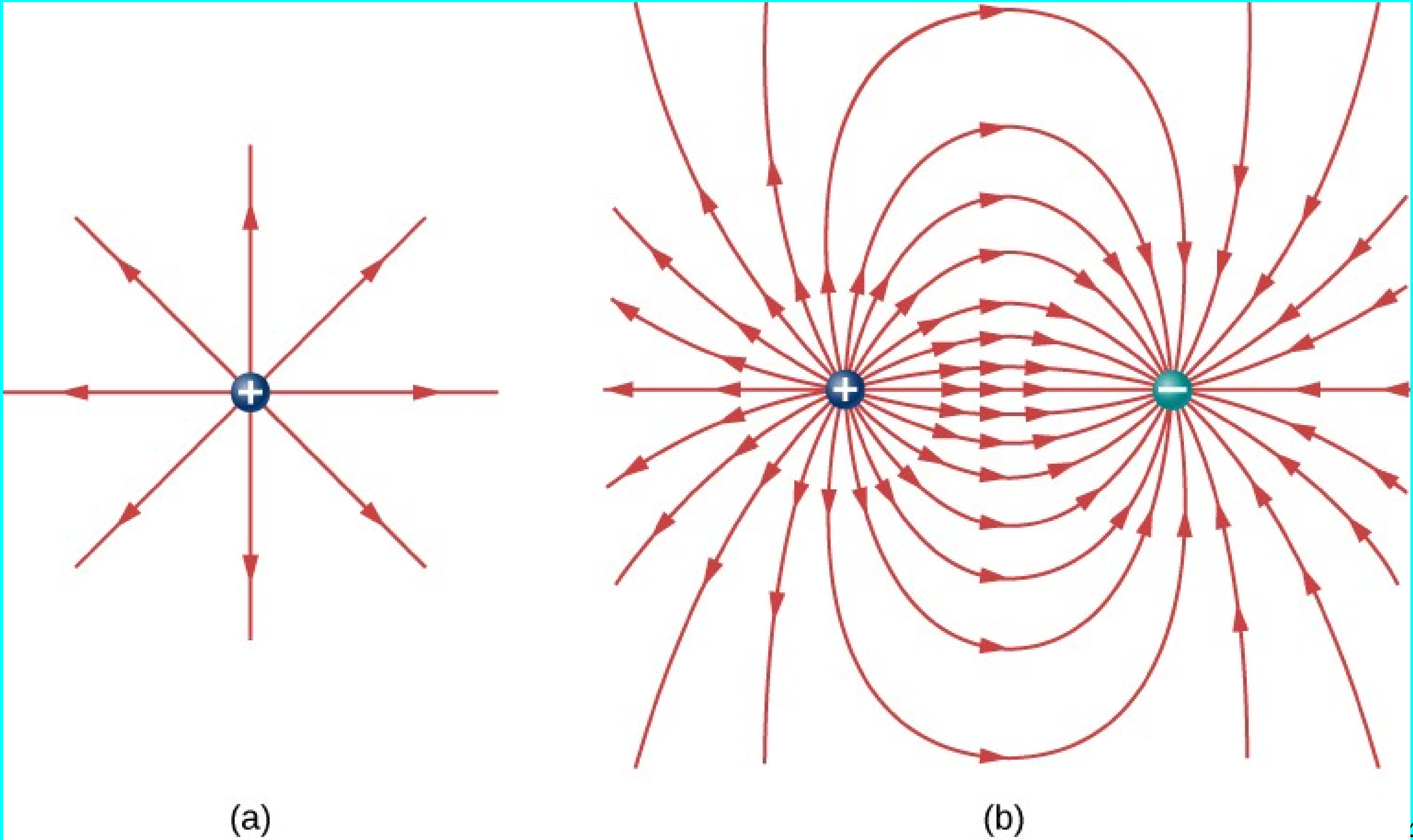
E-field of a pair of opposite point charges



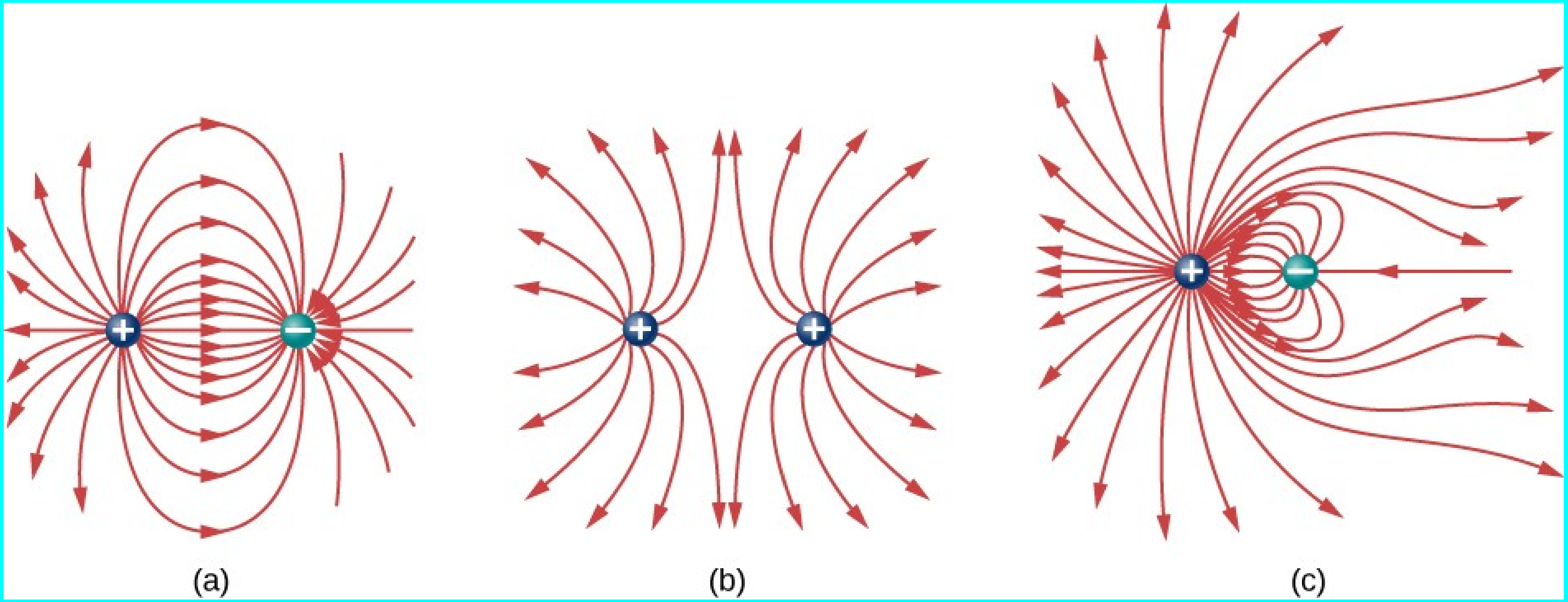


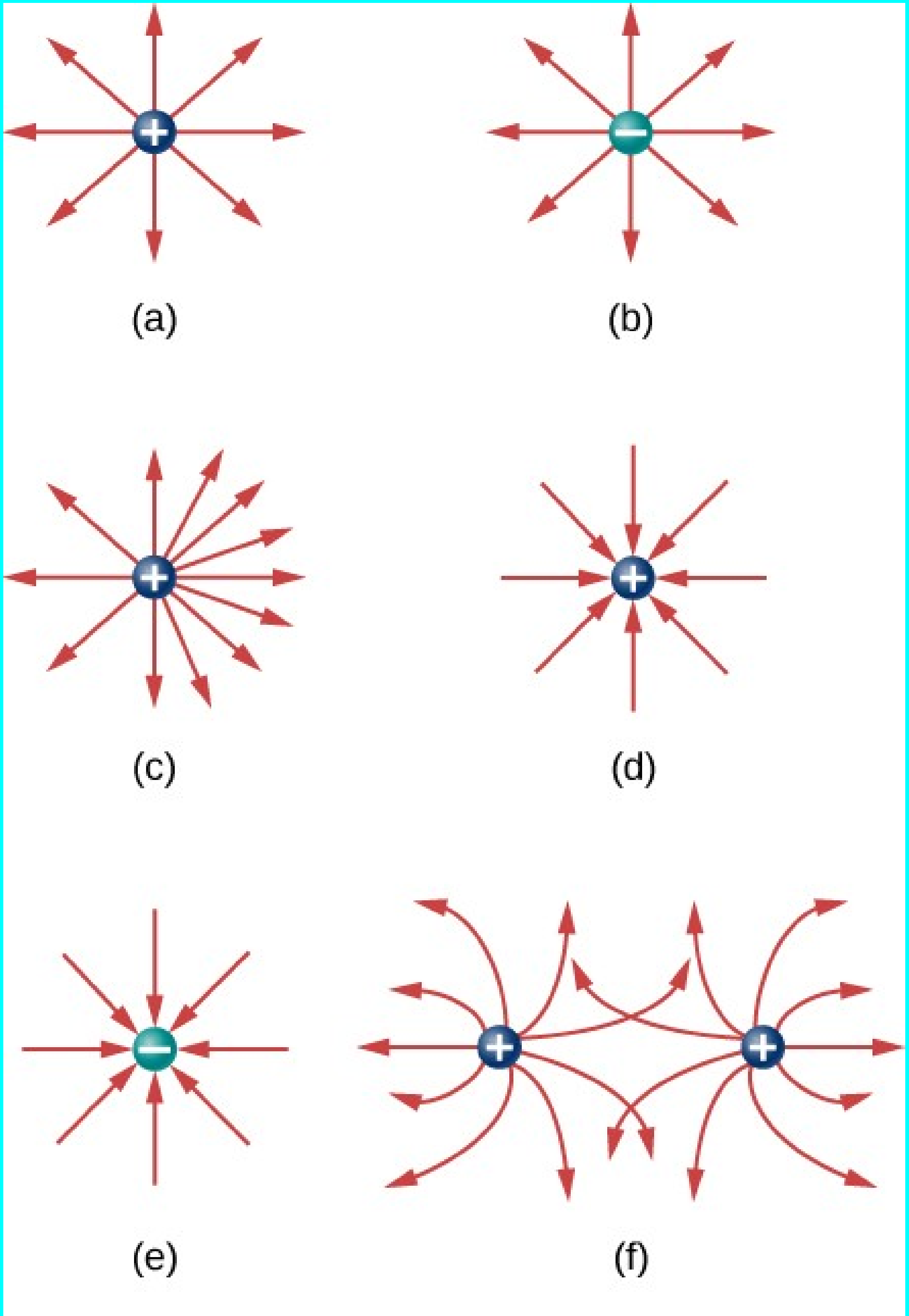
Eight lines begin on +q . . .
q
so 16 lines begin on +2q . . .
2q
and eight end on −q.
−q
(a)
(b)
(c)
Eight lines begin on each +q.
q
q
Eight lines begin on +q
and eight end on −q.
−q
+q
Eight lines begin on +q.
Four go to infinity
and four end on −q/2.
−q/2
q
(d)
(e)
(f)

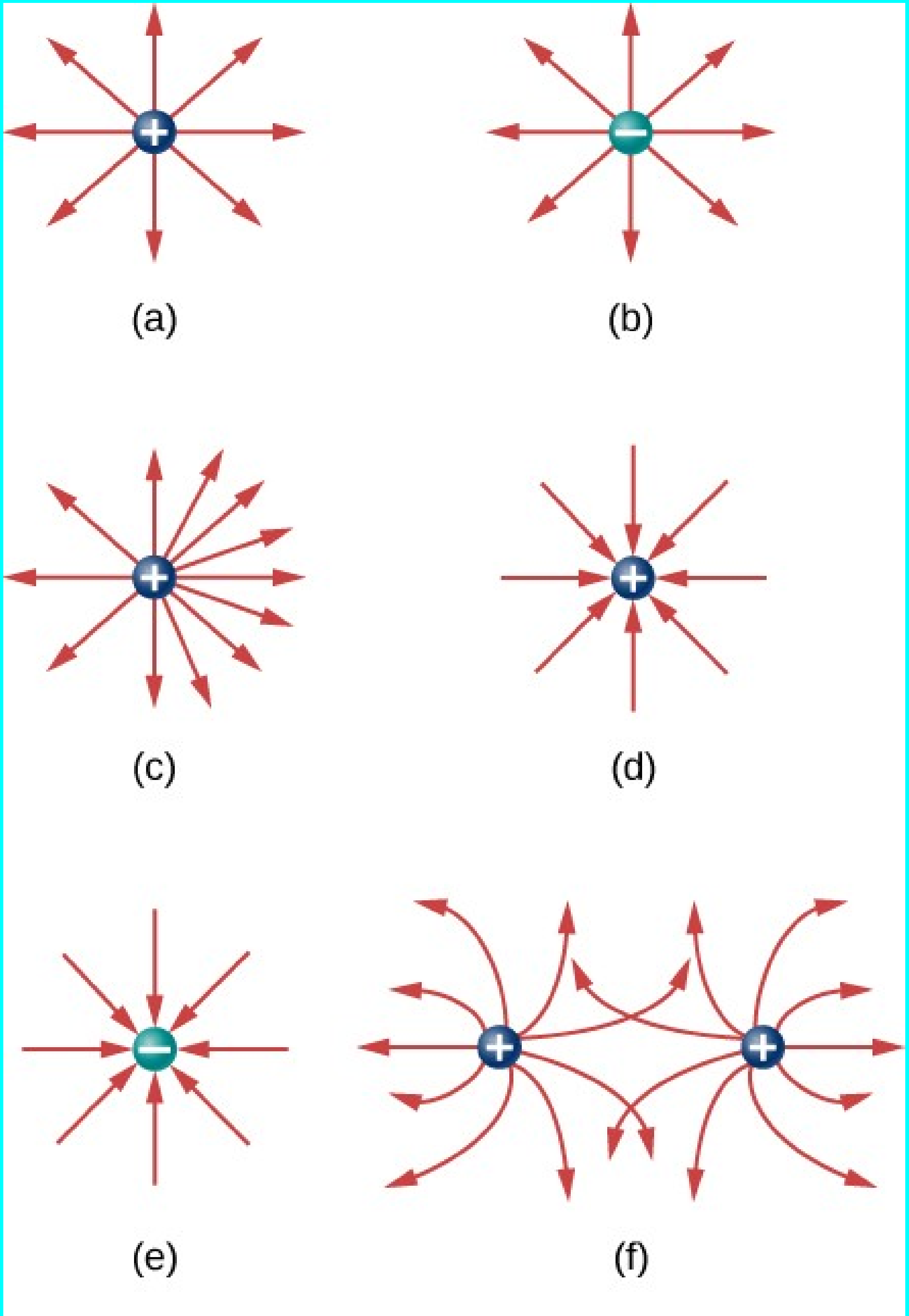
Field line views



More field line views




(a)
(b)
(c)
(d)
(e)
(f)



Positive charges “emit” field lines.

Negative charges “absorb” field lines.

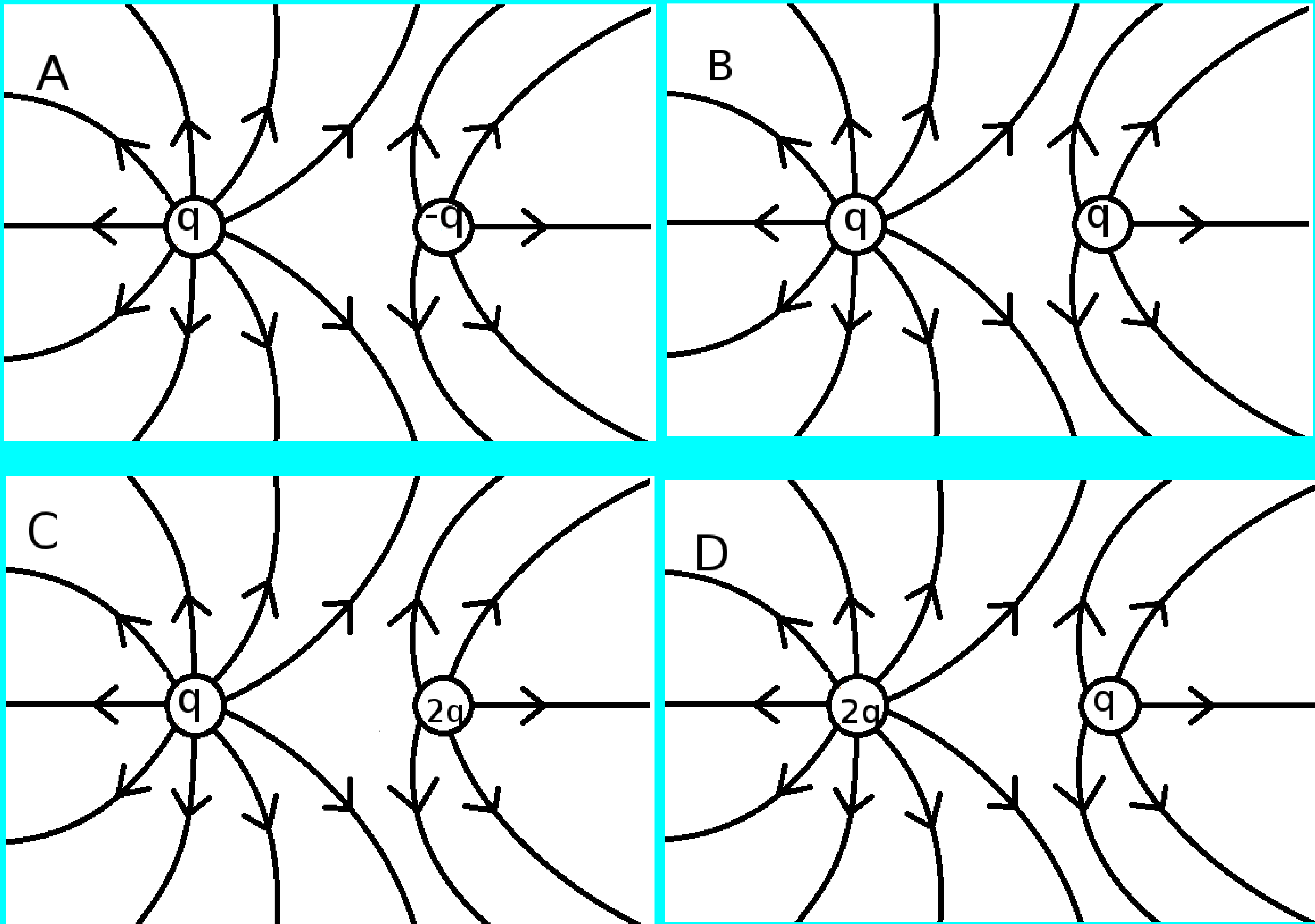
Field lines begin at + charge and end at infinity or negative charge.

The tangent to an electric field line gives direction of force

Electric field lines do not cross

PheT …
Charges and fields
Electric field of dreams

Which set of field lines matches the charges shown?



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

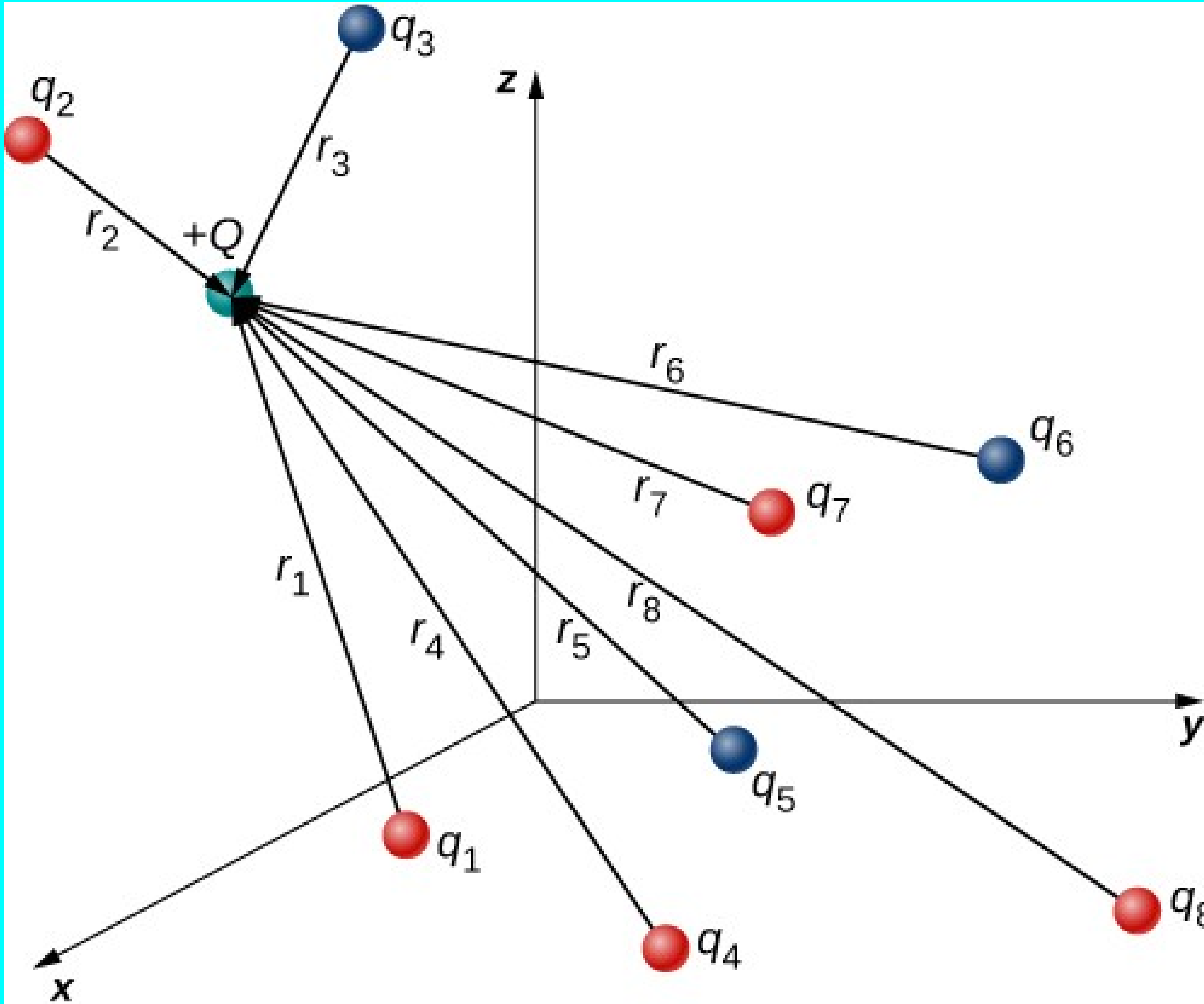
Coulomb's Law, Vector Form

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

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

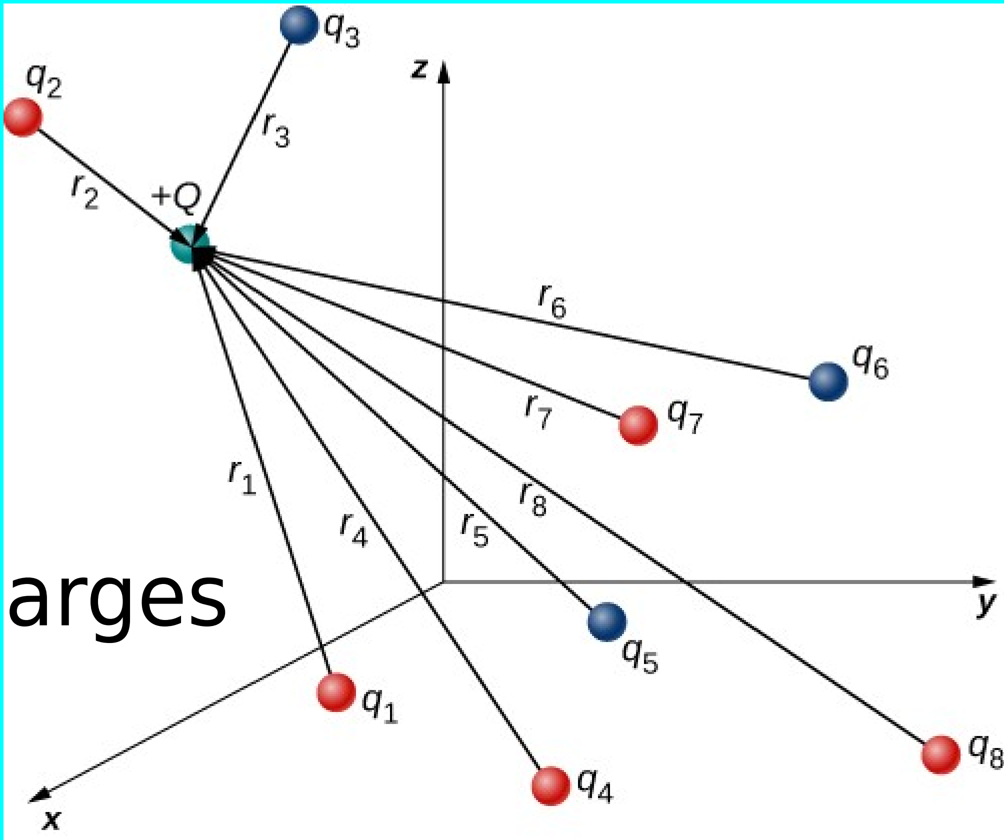
$$\vec{F}_{net} = Q \sum_{n=1}^{N} k \frac{q_n}{r_n^2} \hat{r}_n$$

$\hat{r}$



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