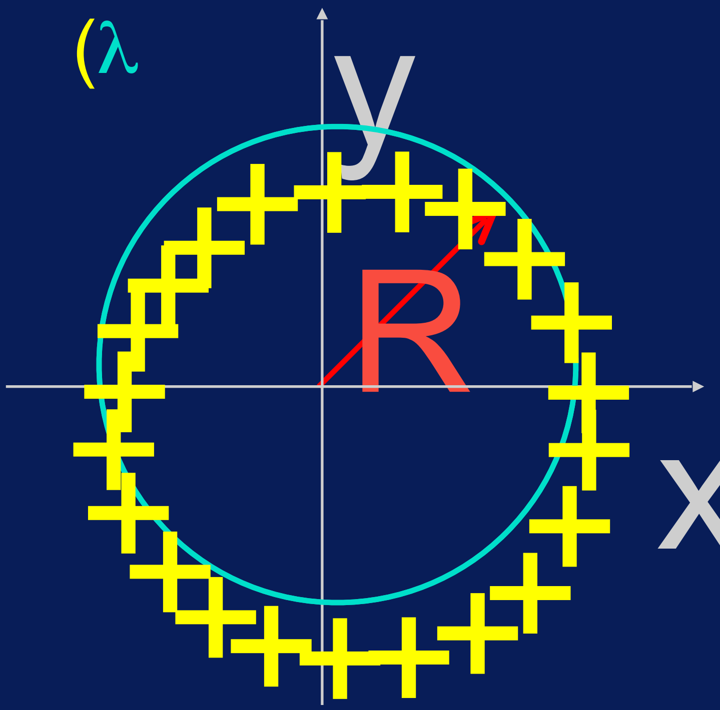
E field from (more) continuous charge distributions…

Lecture 4.

Reading for next time

- 22-2 to 22-3: Flux and Gauss Law

Consider a circular ring with a uniform charge distribution (λ charge per unit length). The total charge of this ring is +Q.



The electric field at the origin is

(a) zero

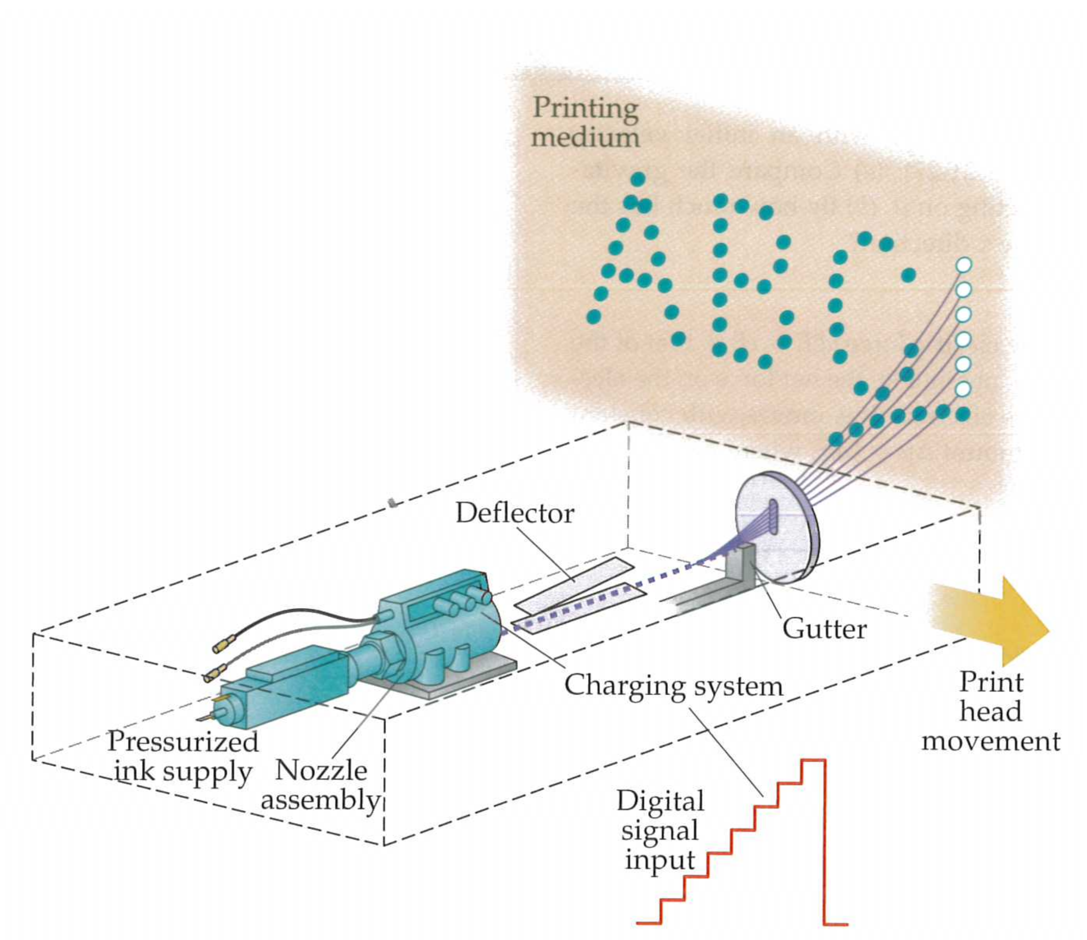
(b) $\frac{k2\pi\lambda}{R}$

(c) $\frac{k\pi\lambda R}{R^2}$

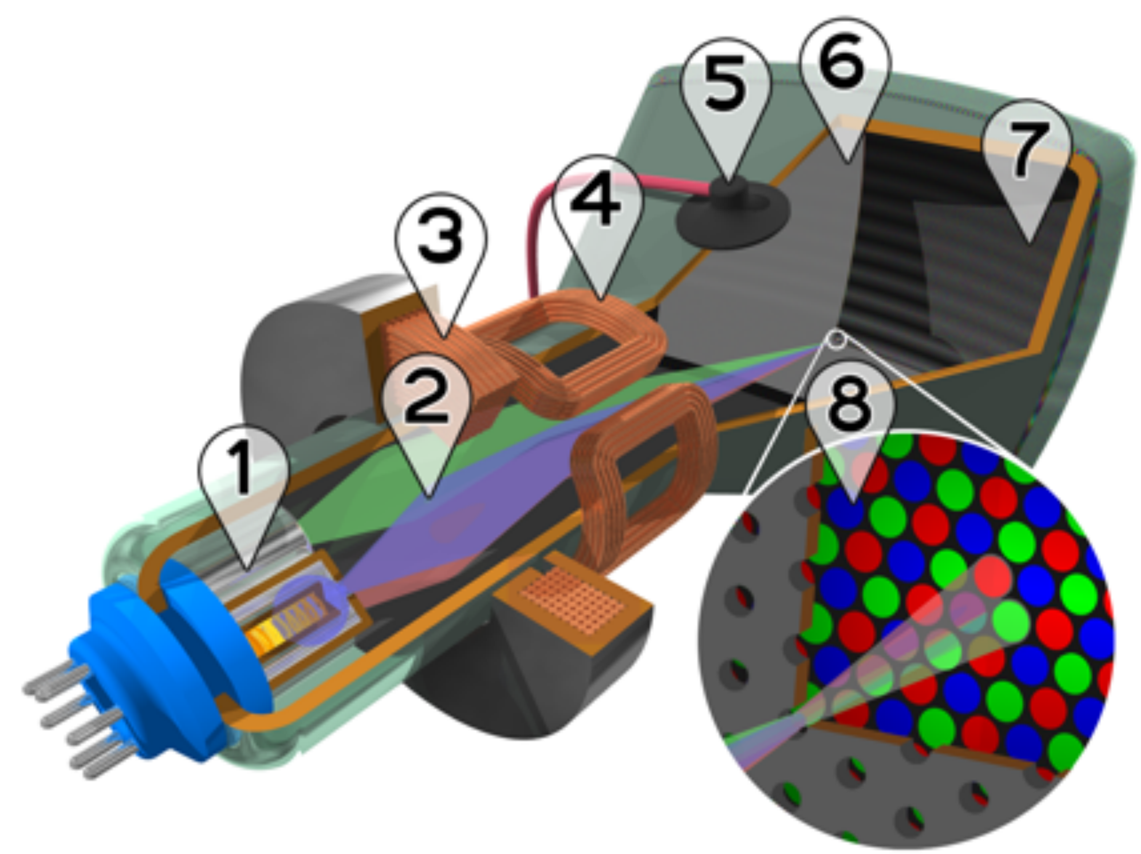
Clicker 4-1

Demo: Application of forces generate by the E field

- Use the definition of the Electric field: $\vec{F}_{\mathrm{Net},0} = q_0 \vec{E}$



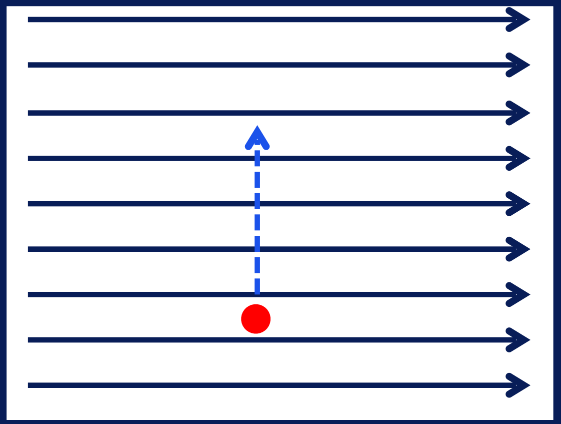
Ink jet printer

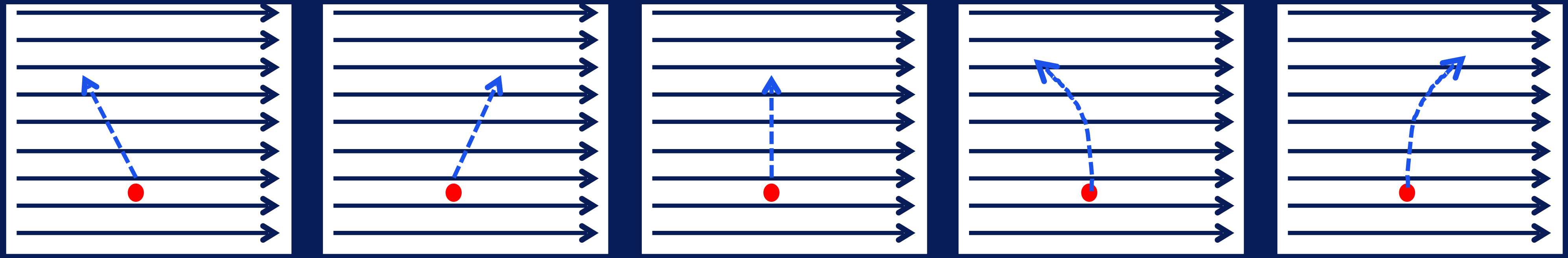


Cathode Ray Tube (CRT)

An electron is fired upward at speed v_0 toward the top of the page as shown. A uniform electric field points to the right.

Which trajectory best represents its motion:





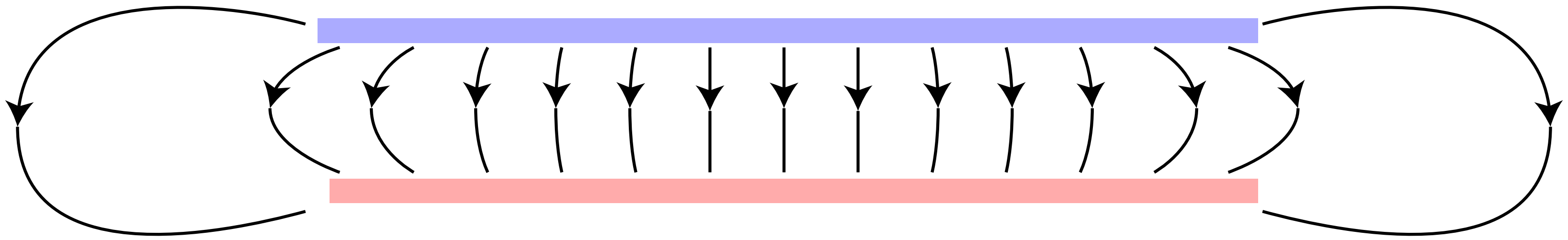
(A) (B) (C)

(D) (E)

Clicker 4-2

Clicker 4-3: Field lines

- What scenario best explains the charge distribution that created the field lines pictured below?



(A) Blue plate is +, red plate is -

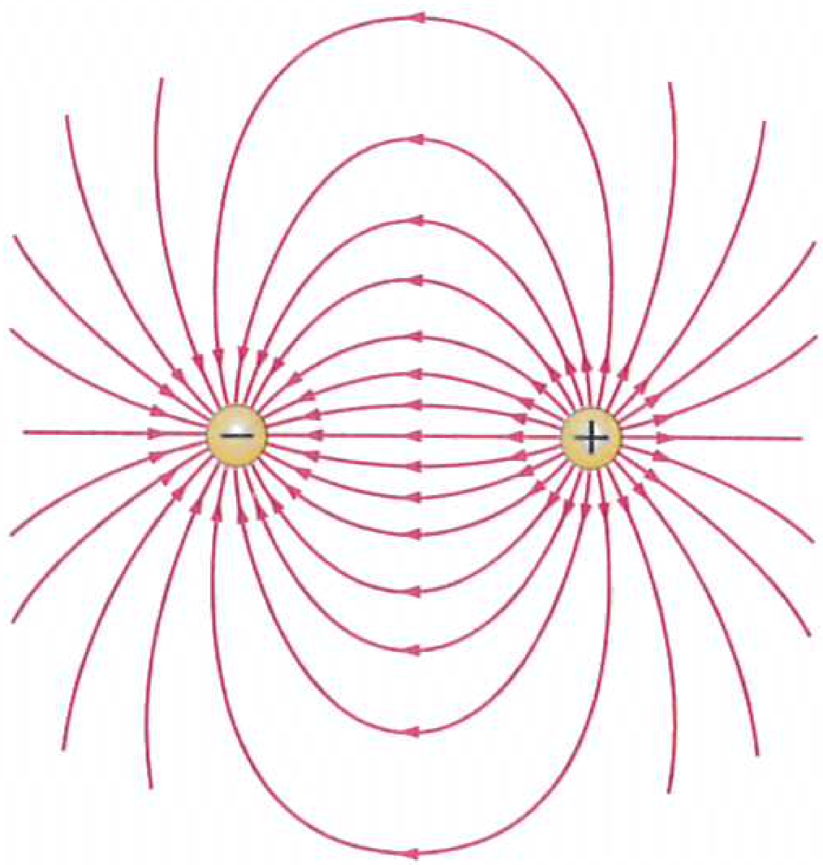
(B) Blue plate is 0, red plate is -

(C) Blue plate is -, red plate is +

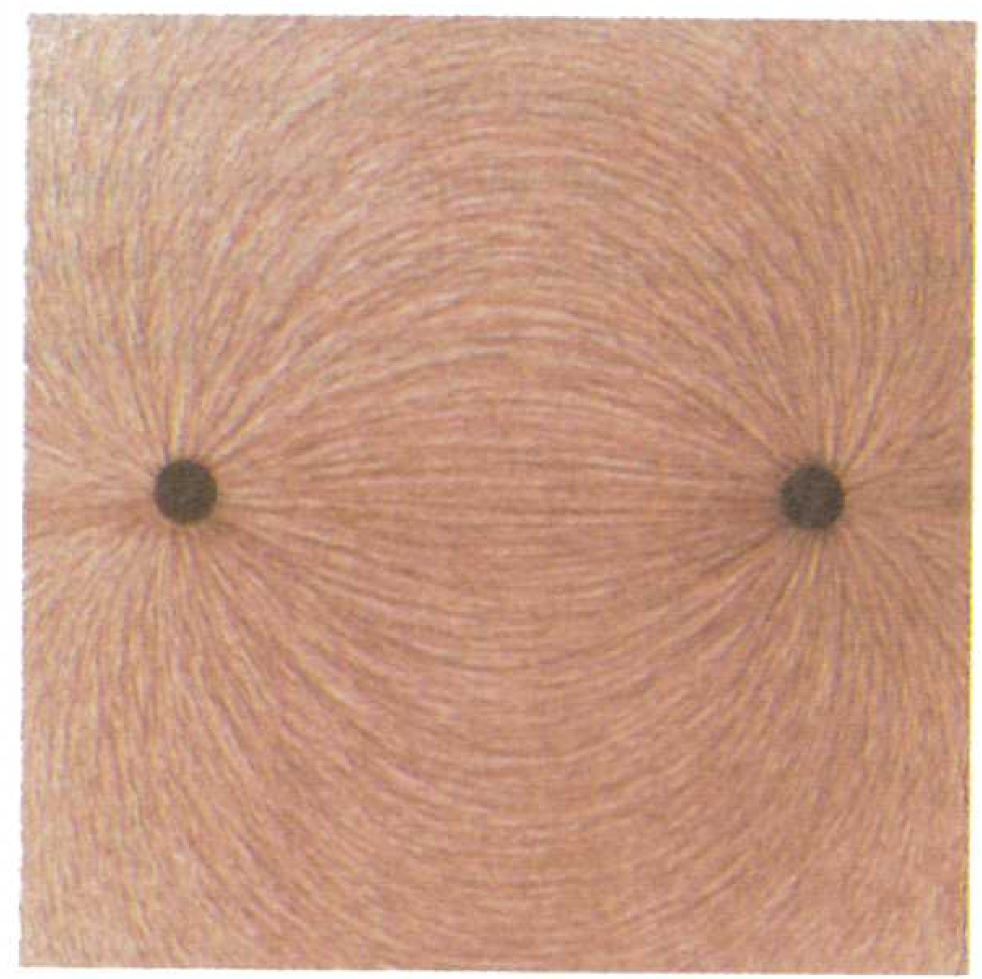
(D) This scenario is impossible

Demos for field lines

Field lines: Opposite charges

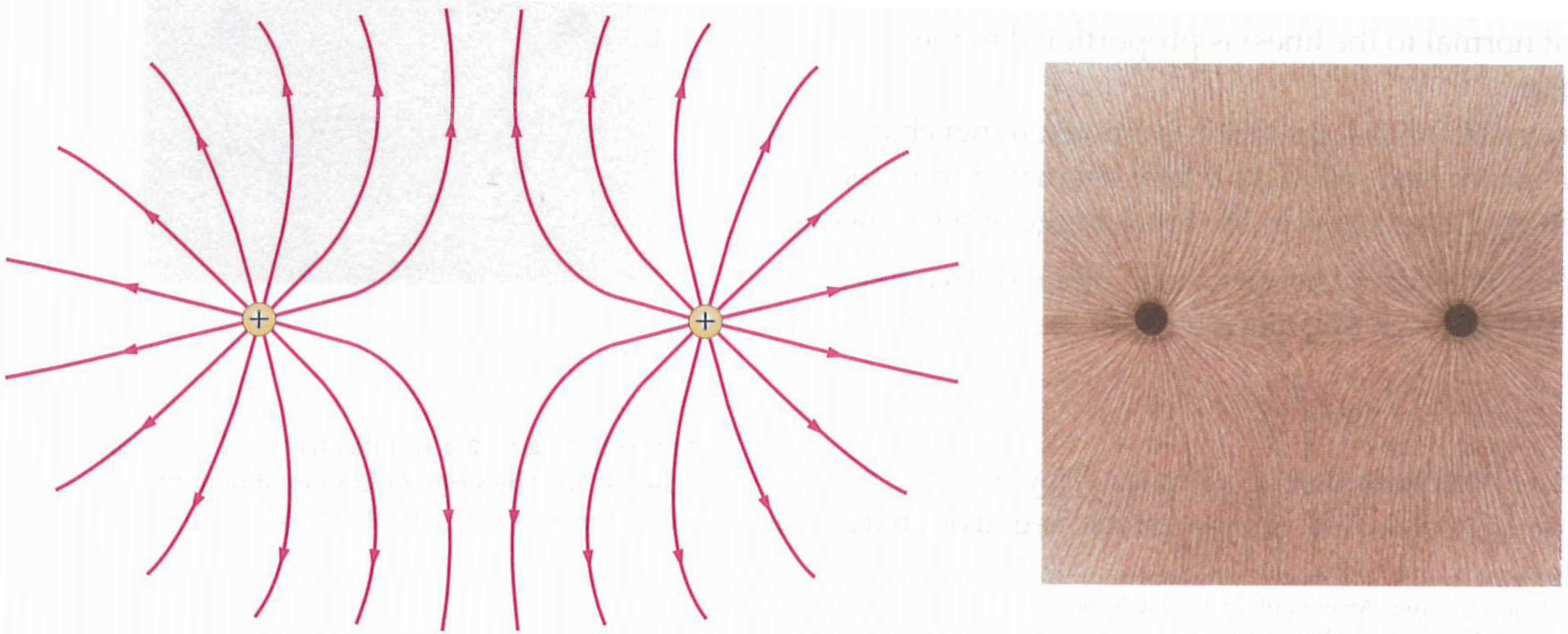


(a)



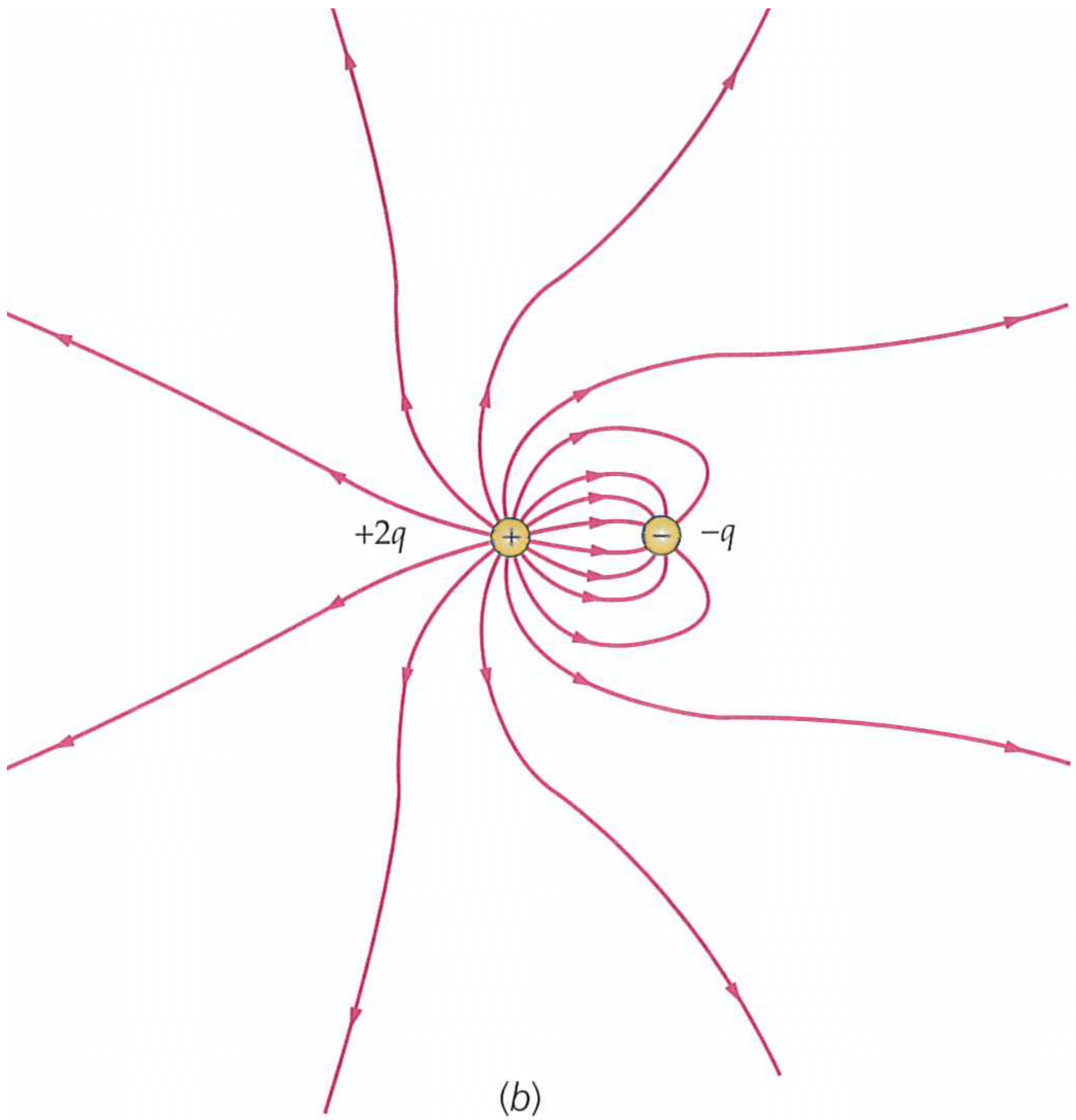
(b)

Field lines: Like charges



(a) (b)

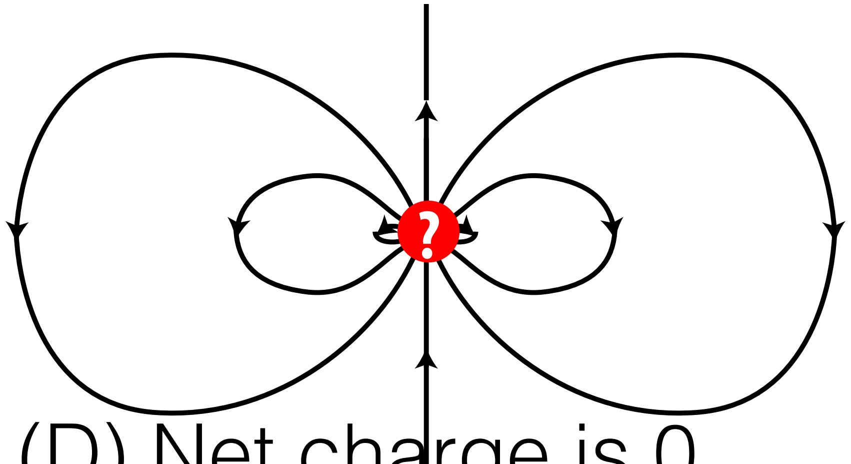
Field lines: Opposite but unequal charges



(b)

Clicker 4-4: Field lines

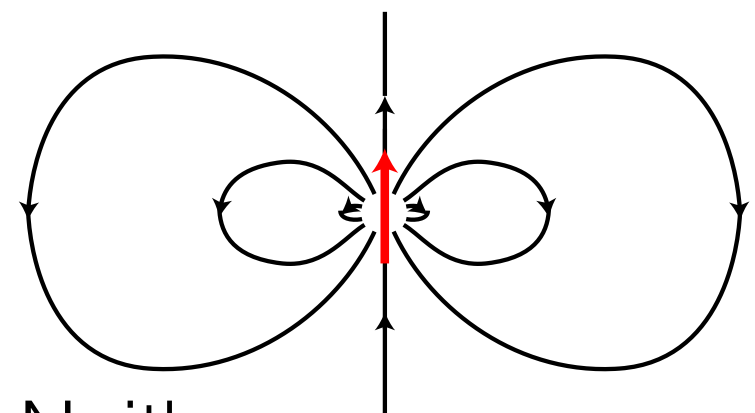
- What scenario best describes the charge distribution that created the field lines pictured to the right?



(A) Ball is + (B) Ball is - (C) Impossible (D) Net charge is 0

Clicker 4-5: What is the scaling of the E field?

- 3-7: What expression is consistent with the magnitude of the E field generated by a dipole moment p?



$[r] = \mathrm{m}$ $\quad [k] = \mathrm{N} \cdot \mathrm{m}^2/\mathrm{C}^2$ $\quad [E] = \mathrm{N}/\mathrm{C}$

$[p] = \mathrm{C} \cdot \mathrm{m}$ $\quad [q] = \mathrm{C}$

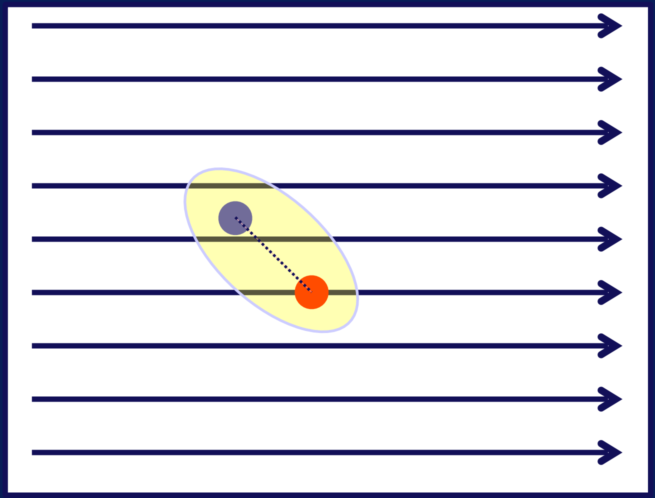
(A) $\vec{E} = \frac{k}{r^3}\left[3\hat{r}(\hat{r} \cdot \vec{p}) - \vec{p}\right]$

(B) $\vec{E} = \frac{k}{r^2}\vec{p}$

(C) Neither

An electric dipole consists of two equal and opposite charges, fixed a distance 2a apart. It is placed in a uniform electric field as shown. It will

A. Not translate in any direction
B. Translate horizontally
C. Translate vertically
D. Start to rotate clockwise
E. Start to rotate counter-clockwise



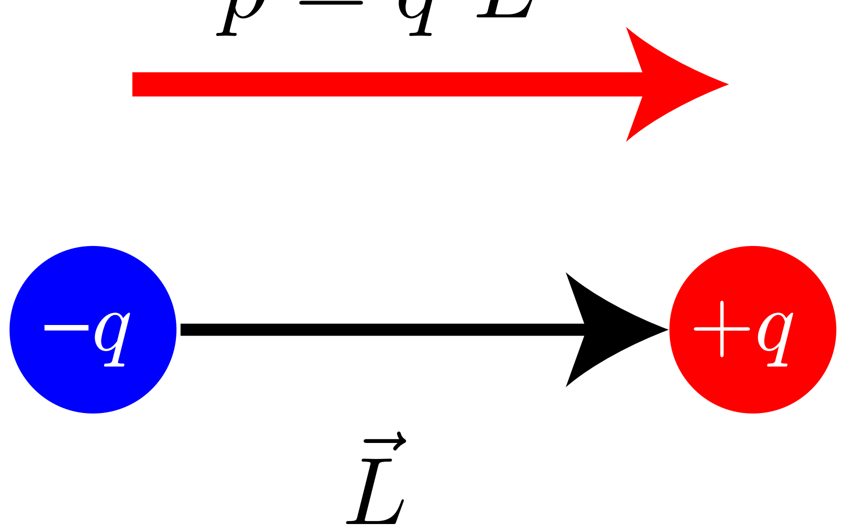
Clicker 4-6

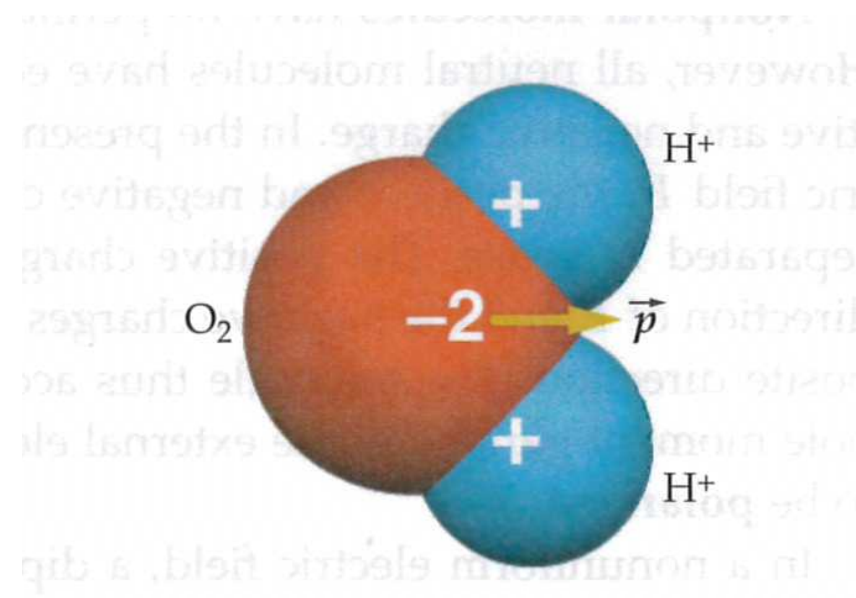
What is a dipole?

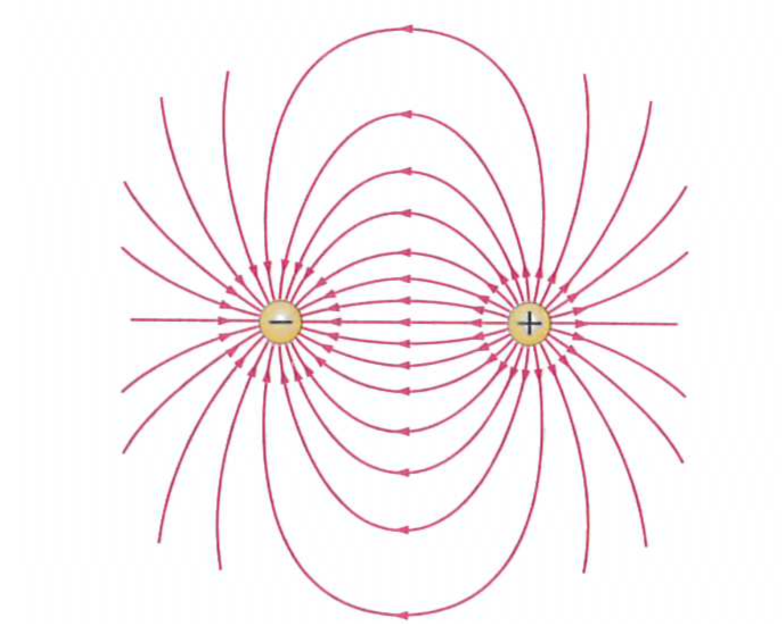
- What happens when a charge distribution has 0 net charge

- Introduce dipole moment:

$$\vec{p} = q\ \vec{L}$$







(a)

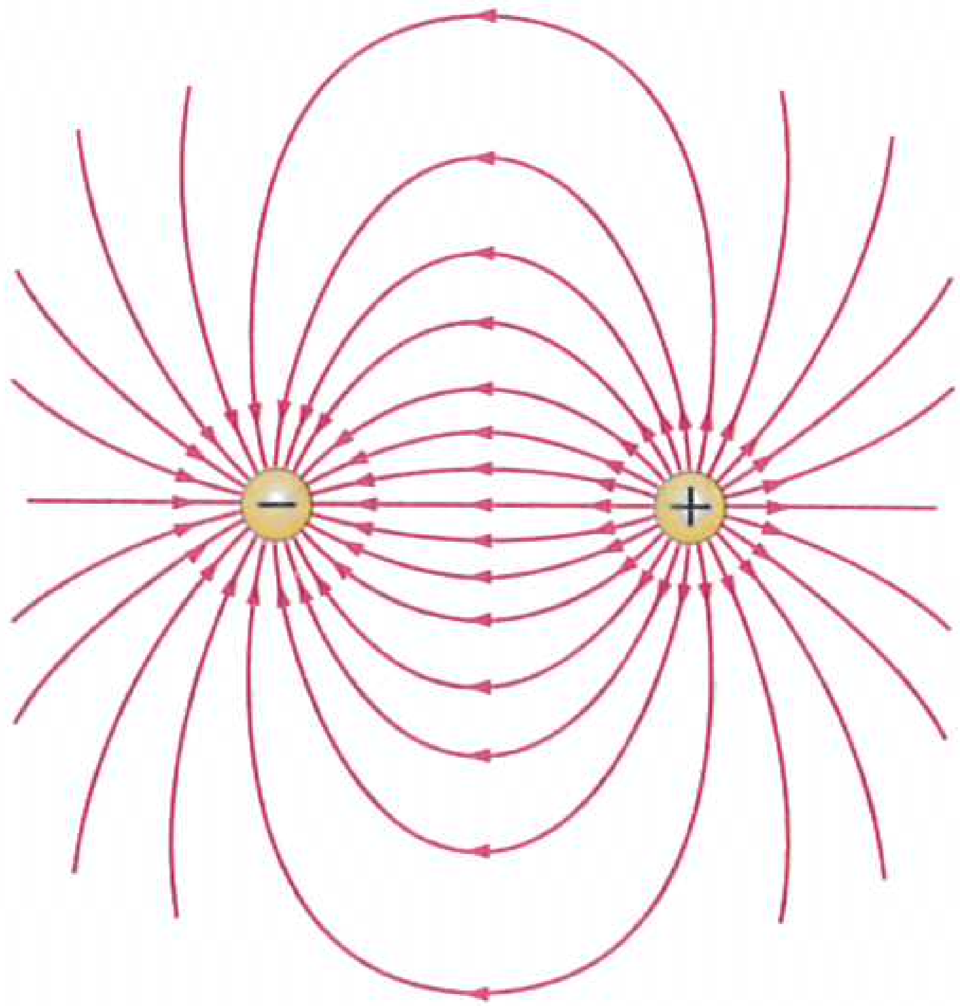
Field from a dipole

- E fields *almost* cancel

- Derive:

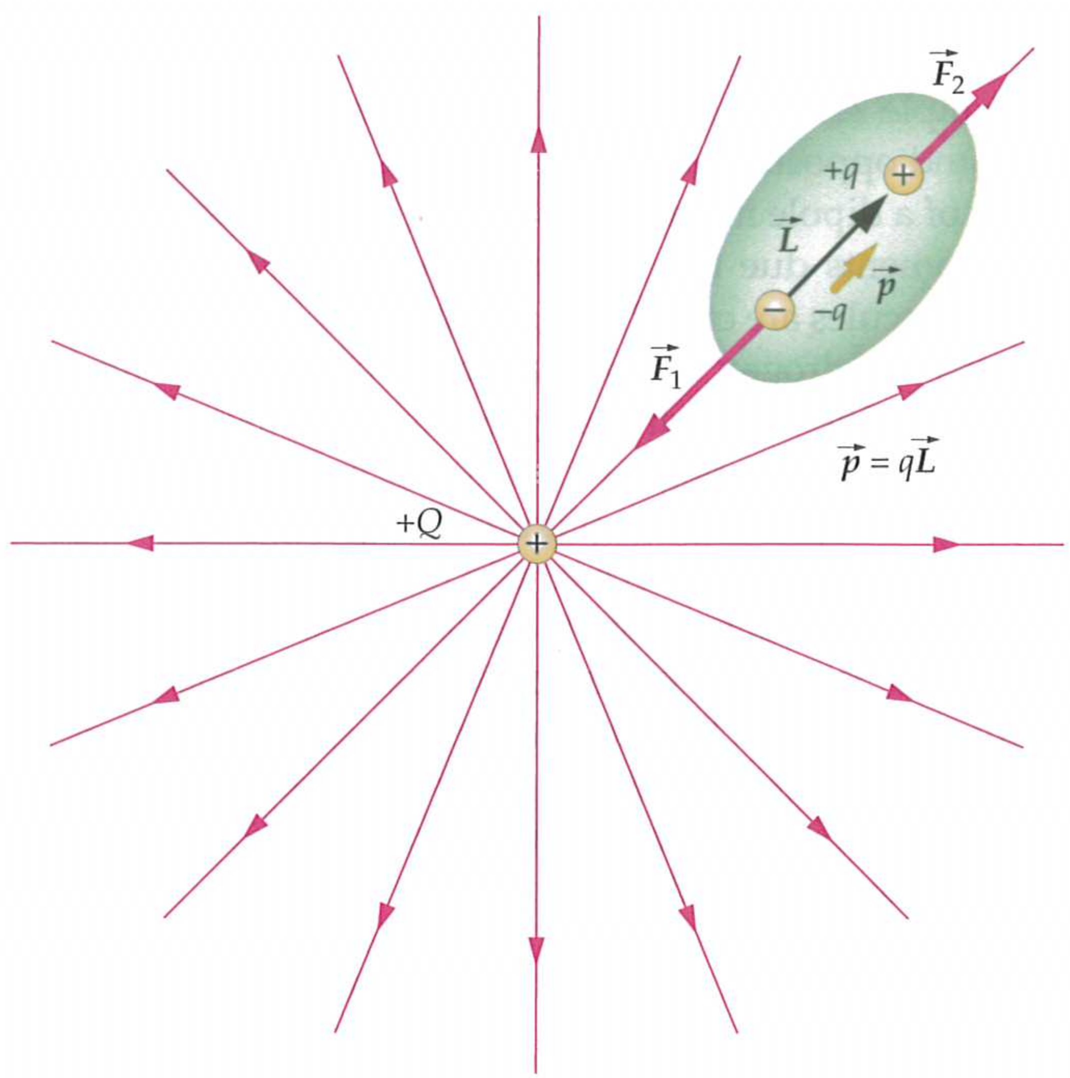
- Result:

$$\vec{E} = \frac{k}{r^3}\left[3\hat{r}(\hat{r}\cdot\vec{p}) - \vec{p}\right]$$



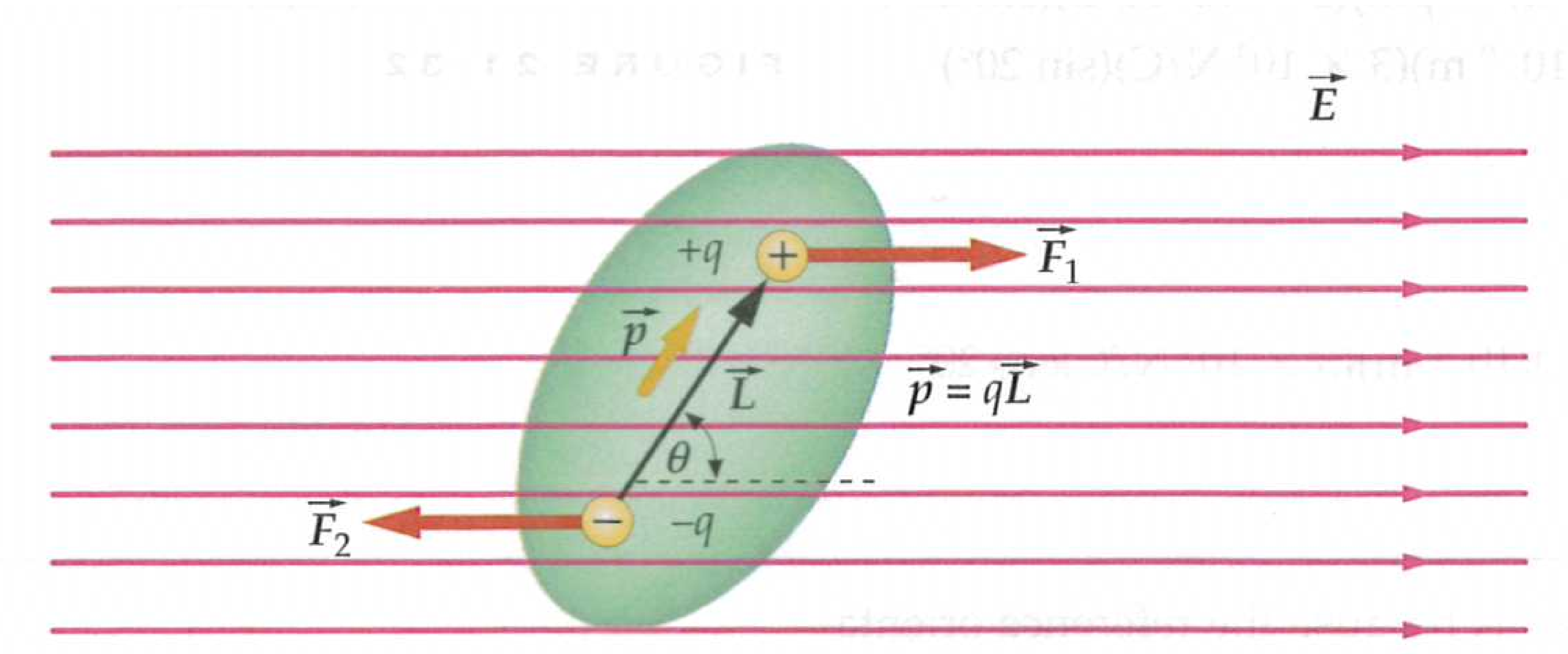
(a)

Dipoles feel force in non-uniform fields



- Dimensional analysis

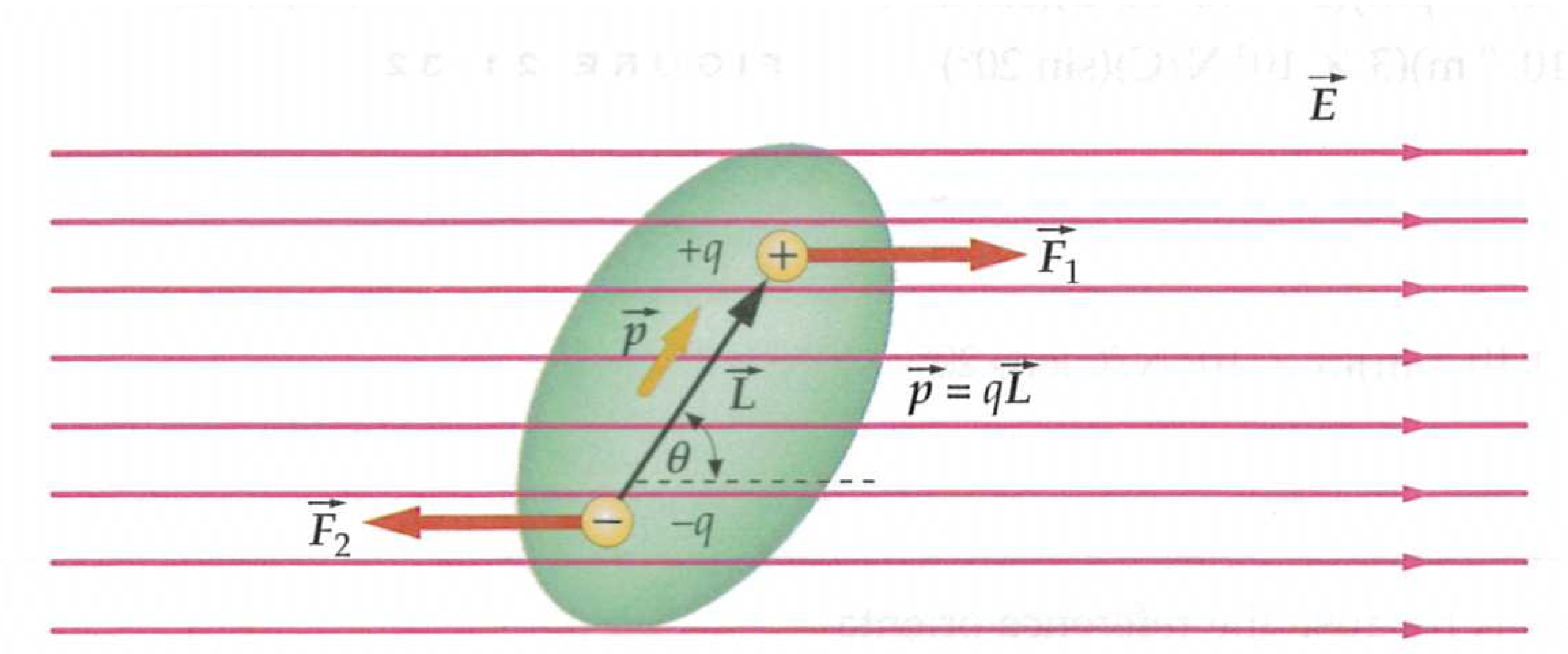
Torque and energy for a dipole in an E field



- Torque: $\vec{\tau} = \vec{r} \times \vec{F}$

- Energy: $dW = -\tau \, d\theta$

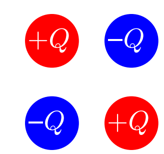
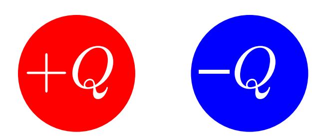
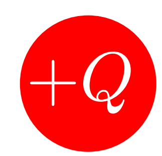
Torque and energy for a dipole in an E field



- Torque: $\vec{\tau} = \vec{p} \times \vec{E}$

- Energy: $W = -\vec{p} \cdot \vec{E}$

Summary of field scaling

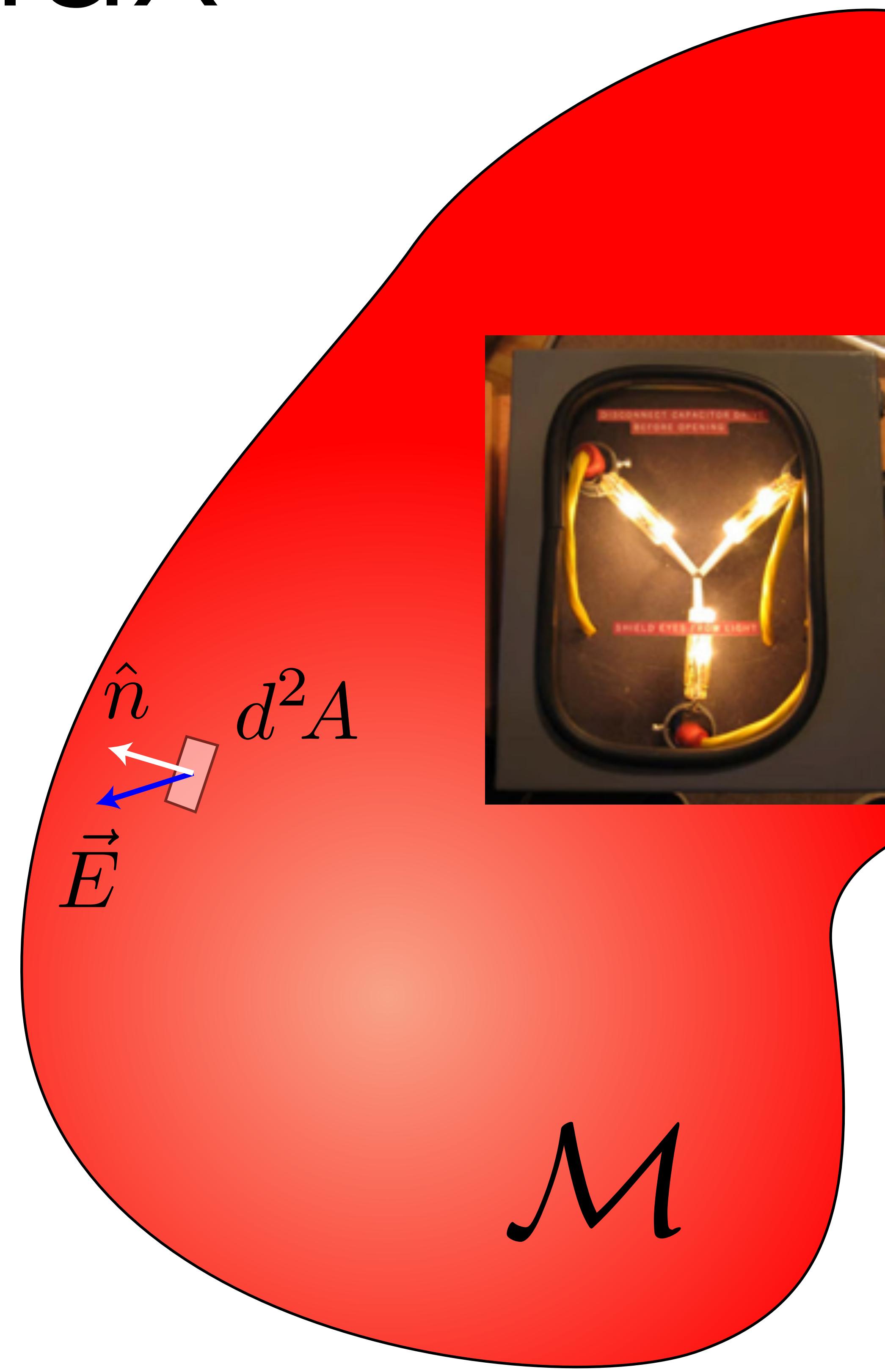
Charge configuration	**Symbol**	**Illustration**	**Asymptotic field**
quadrupole	Q_{ij}		$\propto r^{-4}$
dipole	p_i		$\propto r^{-3}$
point charge	q		$\propto r^{-2}$
line charge	λ		$\propto r^{-1}$
plane charge	σ		$\propto r^{0}$
…			

Electric Flux

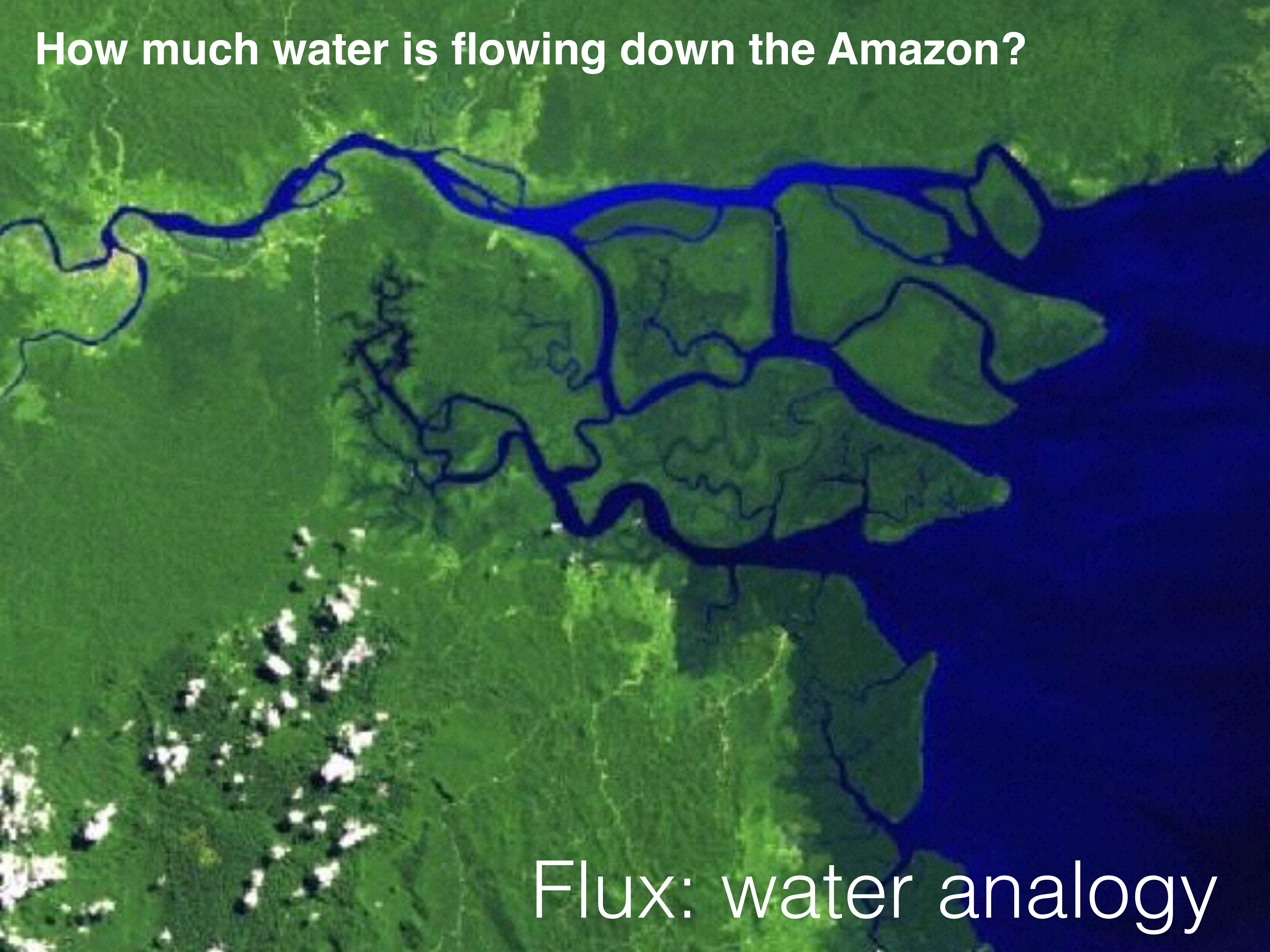
- Definition of Electric Flux:

$$\Phi_{\mathcal{M}} = \oint_{\mathcal{M}} d^2A \; \hat{n} \cdot \vec{E}$$

- Meaning of **flux**:
  ~ Number passing through a surface



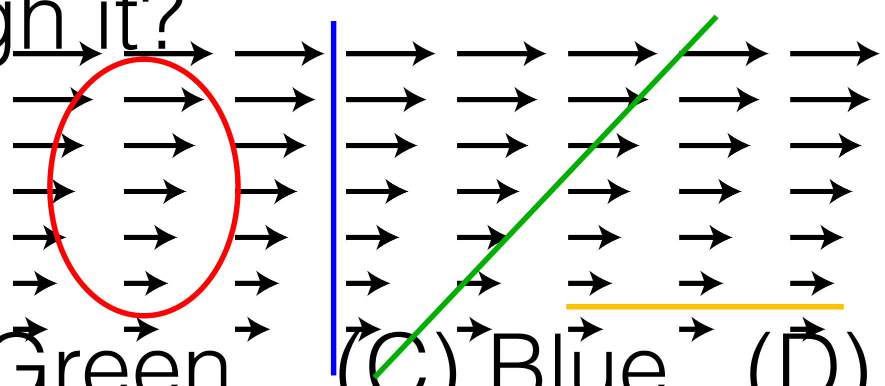
How much water is flowing down the Amazon?



Flux: water analogy

Clicker 4-7: Flux

- Which surface has the greatest magnitude of flux flowing through it?



(A) Red (B) Green (C) Blue (D) Yellow (E) Green & Blue