Things people want explained

- MRI
- Tape recorder
- TVs
- Cameras
- Touchscreens
- Tesla Coils
- Thermal Imaging
- Holograms
- Lasers
- E-M reciprocating engine
- Electrically Commutated Motors
- Optical Storage (CDs)
- 3D glasses
- Regenerative Braking

Things people want explained

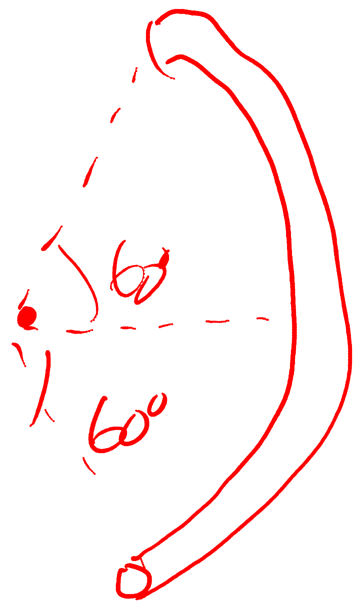
- Geological Magnetism
- Electric Motors
- Telescopes
- Projector
- Speakers/headphones
- Photovoltaics
- Hard drives

Previous classes asked about…

- Graphene
- Electromagnetic drives
- Transformers
- Spectrophotometer
- Eyeglasses
- Waves
- Alternator
- Light & spacetime
- Chemical potentials
- Magnets
- Circuits
- Microscopes
- Radar
- Maglev trains
- Doppler effect
- Tasers
- Cataracts, laser surgery
- Electromagnets

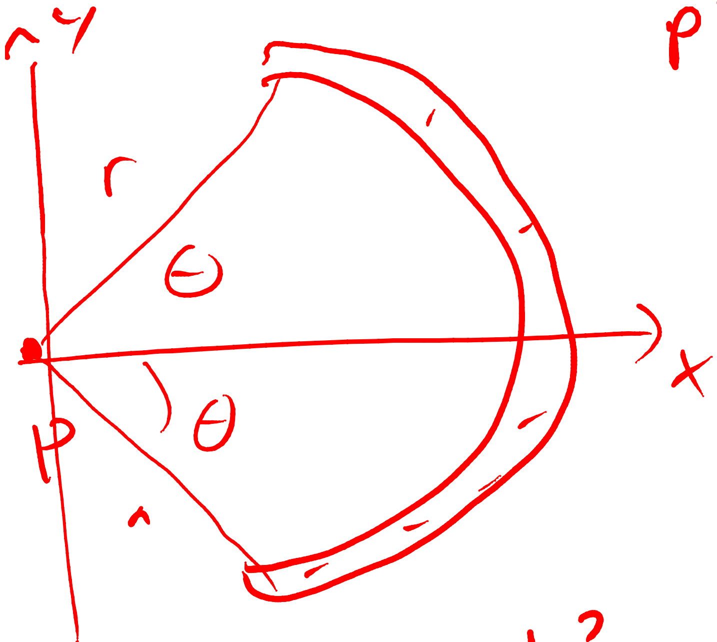
Previous classes asked about…

- Eyes/vision
- Batteries
- Chemical potentials
- Circuits
- Electromagnets
- Semiconductors
- Bio-electrical signals
- Fiber optics



Plastic Rod, total charge Q.

What is E at the center of it's radius of curvature?



plastic rod, charge $-Q$

P at center of curvature

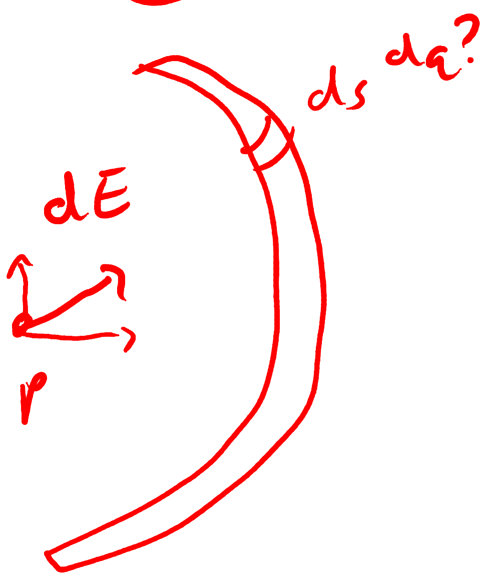
What is $\vec{E}$ @ P? $\theta = 60°$

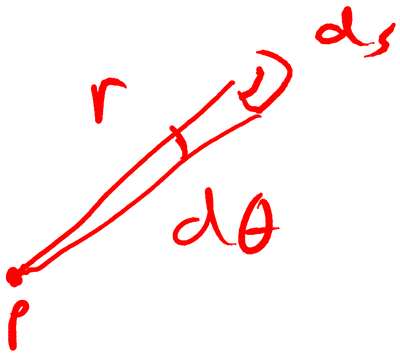
get dE_y, dE_x

$dq = \lambda \cdot ds$ $\quad (\lambda = Q/L)$

$dE_x = dE \cdot \cos\theta$

$$= \frac{k\,dq}{r^2}\cos\theta = \frac{k\lambda\,ds}{r^2}\cos\theta$$





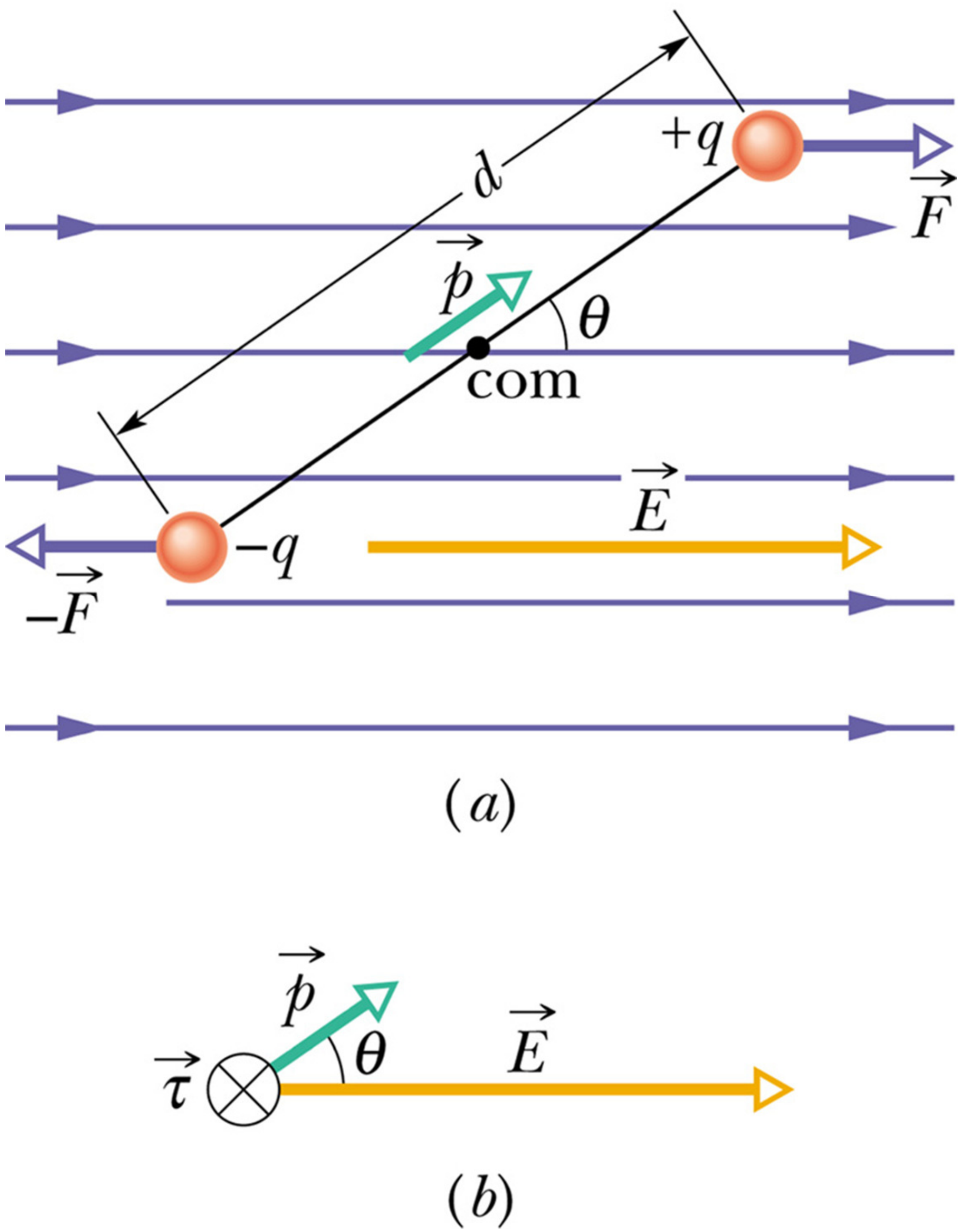
$$ds = r\,d\theta$$

$$dE_x = \frac{k\lambda(r\,d\theta)}{r^2}\cos\theta$$

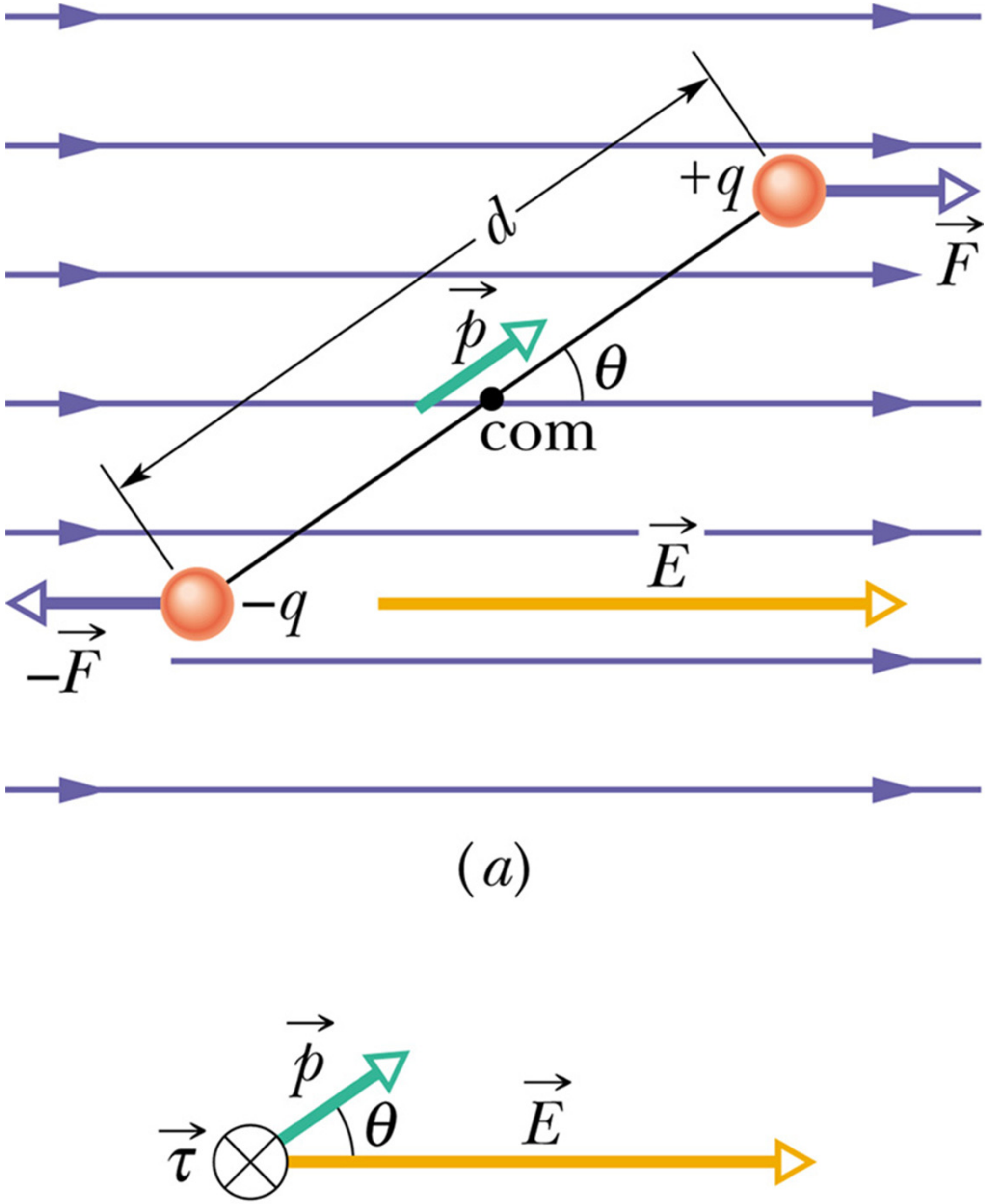
$$E_x = \int dE_x = \frac{k\lambda}{r}\int_{-60}^{60^\circ} \cos\theta\,d\theta$$

$$= \frac{k\lambda}{r}\Big|_{-60}^{60} \sin\theta$$

$$\vec{E} = \quad E_x = \frac{k\lambda}{r}\left[\sin 60^\circ - \sin(-60)\right] = 1.73\,\frac{k\lambda}{r}$$



You work this one out
(see handout)



(a) (b)

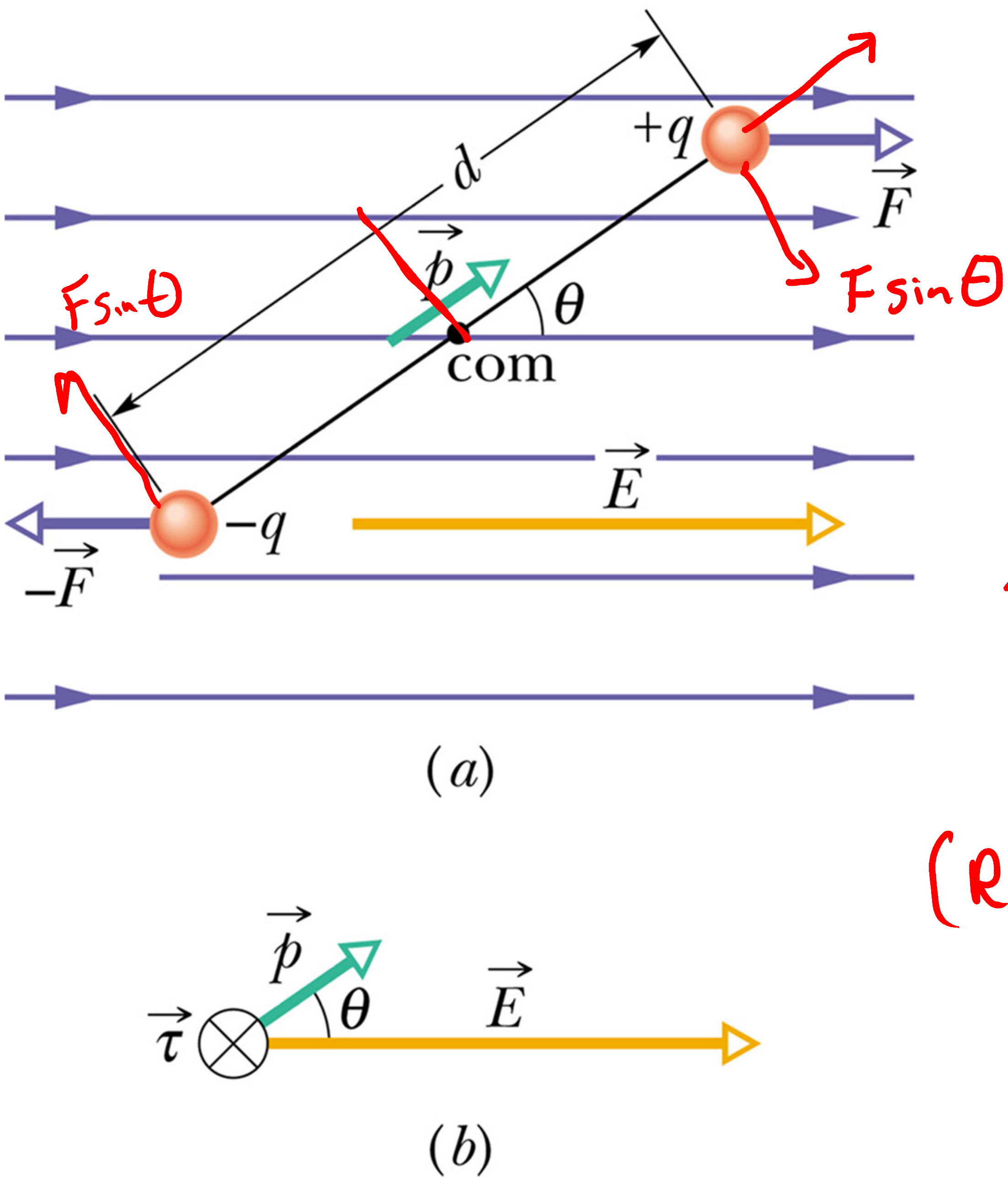
1) Forces on each charge already on there.

Net force:

$$F\hat{x} + (-F\hat{x}) = 0$$

How big is $|\vec{F}|$?

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



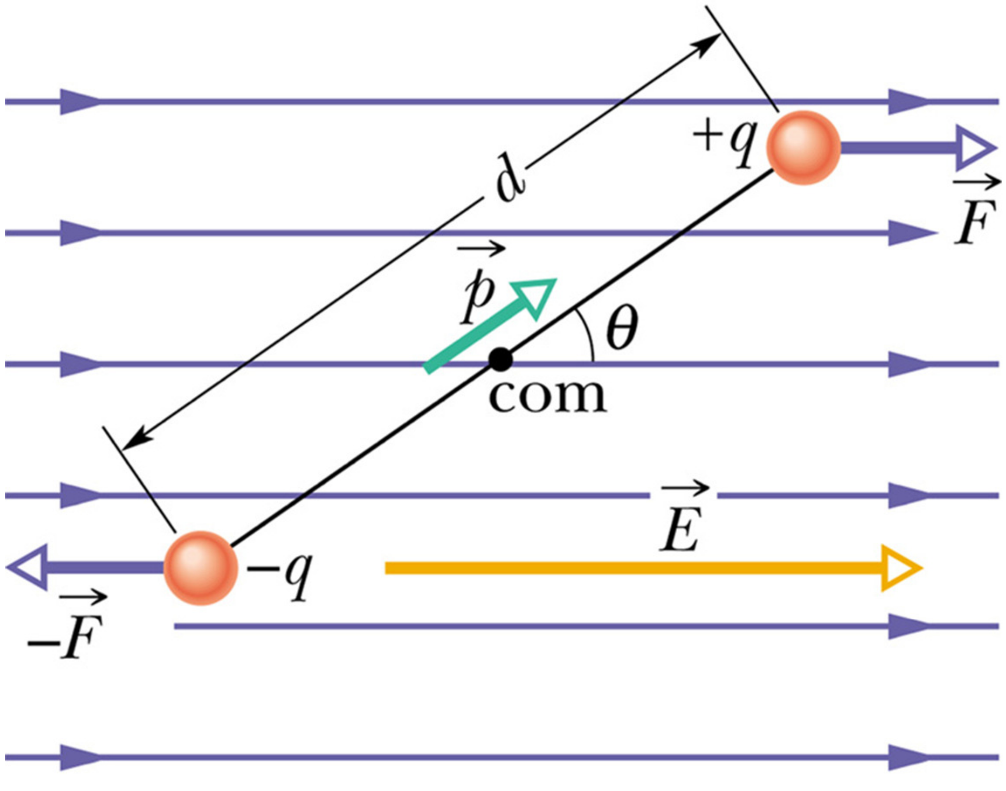
2) Torque?

Each charge is torqued around c.o.m. by $(F\sin\theta)$ with moment $\left(\frac{d}{2}\right)$

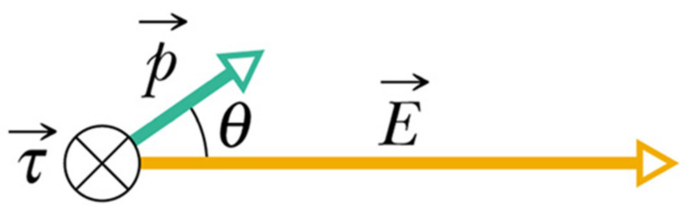
so: $\left(\frac{d}{2}\right)F\sin\theta + \left(\frac{d}{2}\right)F\sin\theta$

$\tau_{TOT} = dF\sin\theta = (qE)d\sin\theta$

(Review Ch. 10, torque)



(a)



(b)

3) if $\vec{p} = q\vec{d}$

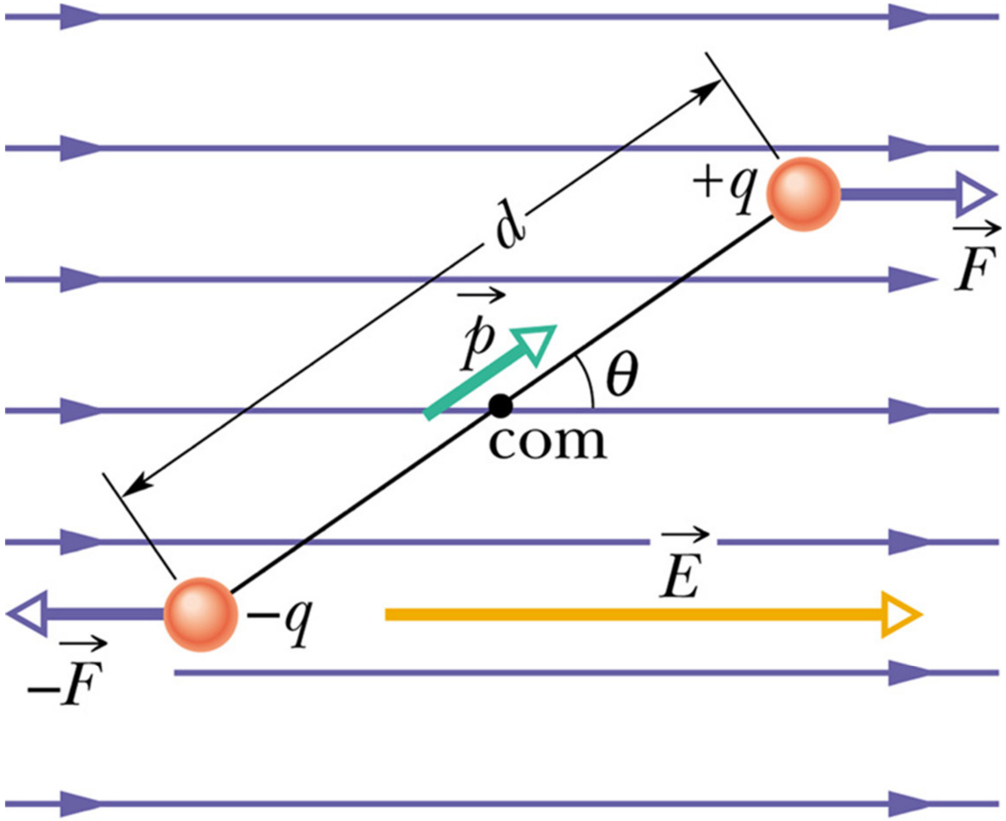
Then $|\vec{\tau}| = q|\vec{E}||\vec{d}| \sin\theta$

$|\vec{\tau}| = |\vec{E}||\vec{p}| \sin\theta$

or $\vec{\tau} = \vec{p} \times \vec{E}$

(Sec. 1.10, cross products)

Review: ⊙, ⊗ for vectors in or out of page

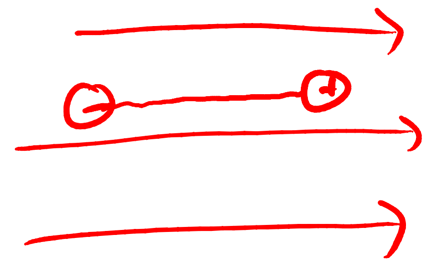


(a)

(b)

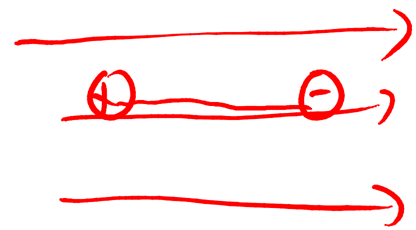
4)

Stable:



$\theta = 0^\circ$

Unstable:



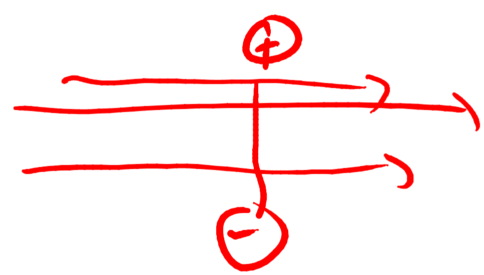
$\theta = 180^\circ$

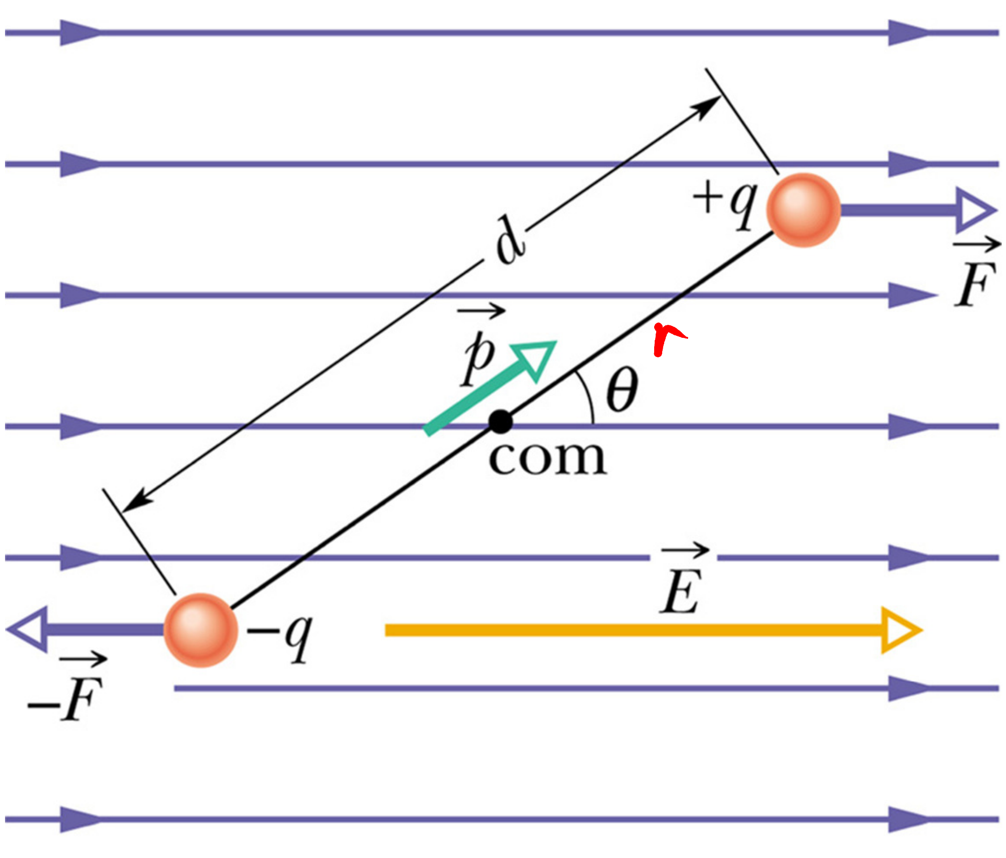
Max τ.

$\theta = 90^\circ$

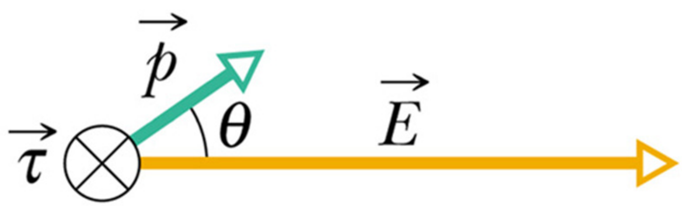
or

270°





(a)



(b)

equal +,- charges

seperated by distance "d".

$\vec{p}$ = "dipole moment"

$\vec{F} = \vec{E} \cdot q$

(Ch.10 torques)

$|\vec{\tau}| = r \cdot F \sin\theta \qquad r = d/2$

$= (\tfrac{1}{2}d)(Eq)\sin\theta \qquad \times 2$

$\Sigma \tau = d\, E q \sin\theta$

$\vec{p} = q\vec{d}$ ↗

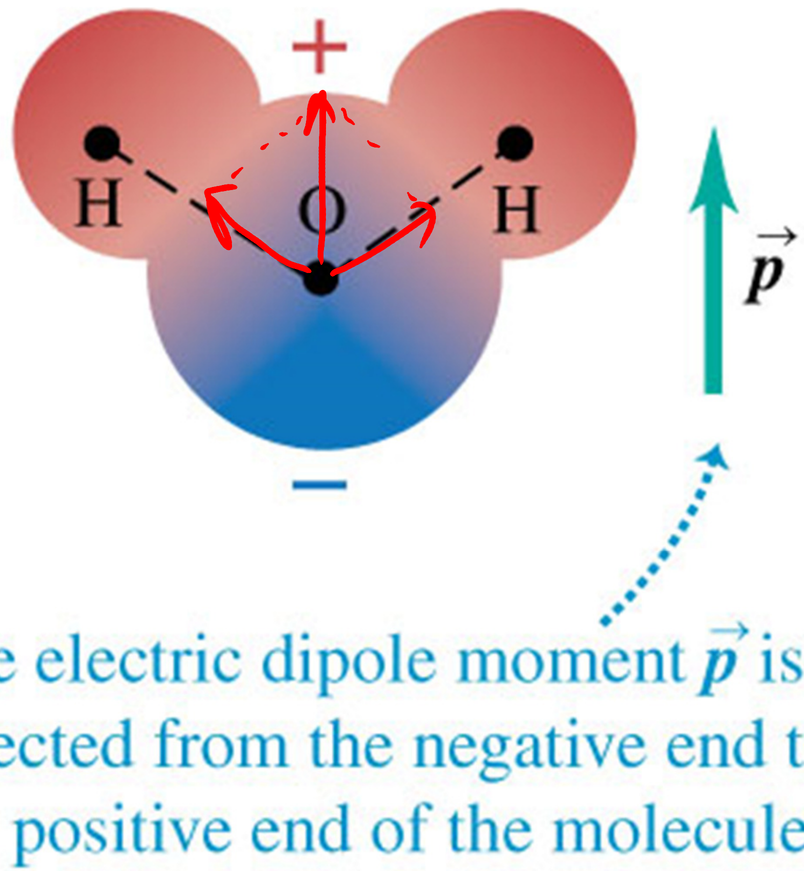
$|\tau| = |p| E \sin\theta$

$\vec{\tau} = \vec{p} \times \vec{E}$

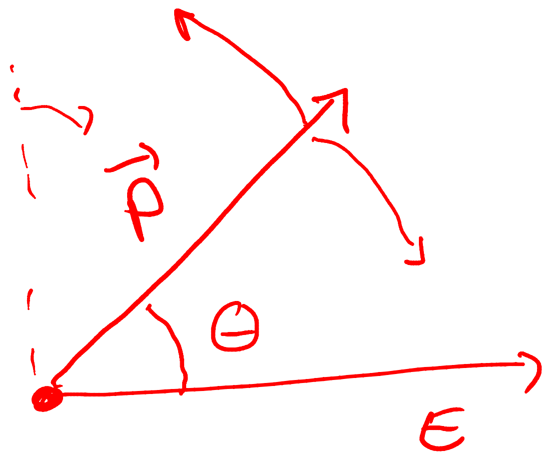
(Sec. 1.10)

Fig. 22-30a

(a) A water molecule, showing positive charge as red and negative charge as blue



Potential Energy



$$dW = \tau \cdot d\theta$$

$$U = -W = \int_{90}^{\theta} dW$$

$$= \int_{90}^{\theta} |p||E| \sin\theta \, d\theta$$

$$= |p||E| \int_{90}^{\theta} \sin\theta \, d\theta$$

$$U = |p||E| -\cos\theta$$

$$U = -\vec{p} \cdot \vec{E}$$

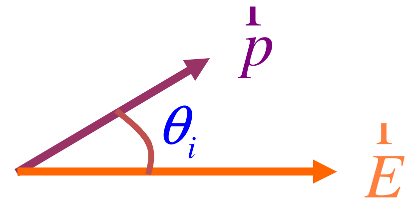


Fig. *a*

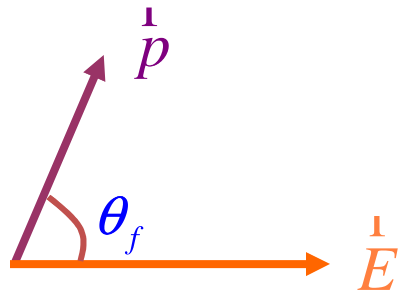


Fig. *b*

Work Done by an External Agent to Rotate an Electric Dipole in a Uniform Electric Field

Consider the electric dipole in fig. *a*. It has an electric dipole moment $\vec{p}$ and is positioned so that $\vec{p}$ is at an angle θ_i with respect to a uniform electric field $\vec{E}$.

An external agent rotates the electric dipole and brings it to its final position shown in fig. *b*. In this position $\vec{p}$ is at an angle θ_f with respect to $\vec{E}$.

The work W done by the external agent on the dipole is equal to the difference between the initial and final potential energy of the dipole:

$$W = U_f - U_i = -pE\cos\theta_f - \left(-pE\cos\theta_i\right)$$

$$W = pE\left(\cos\theta_i - \cos\theta_f\right)$$

An electric dipole is twisted from the first position to the second. What happens to its potential energy “U”?

1. U decreases
2. U increases ✓
3. Nothing

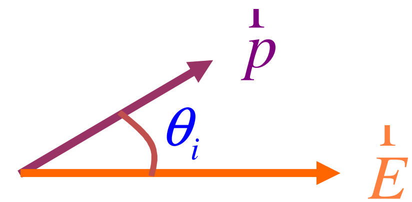
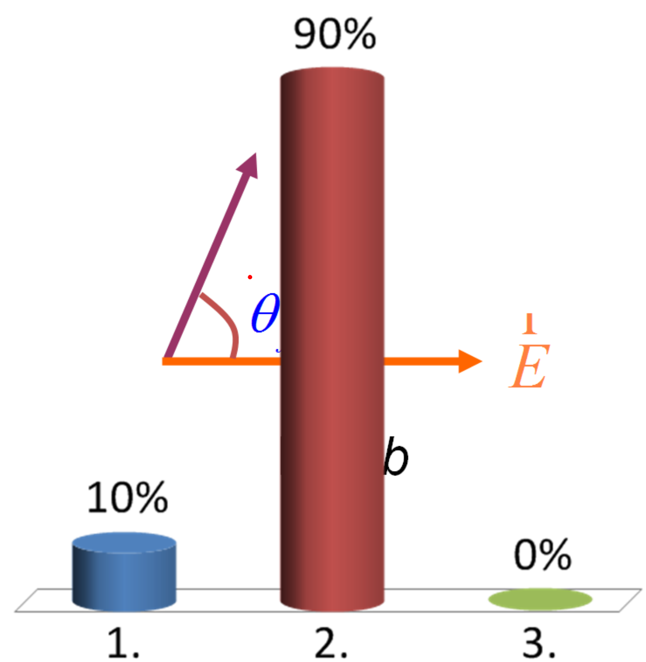


Fig. *a*



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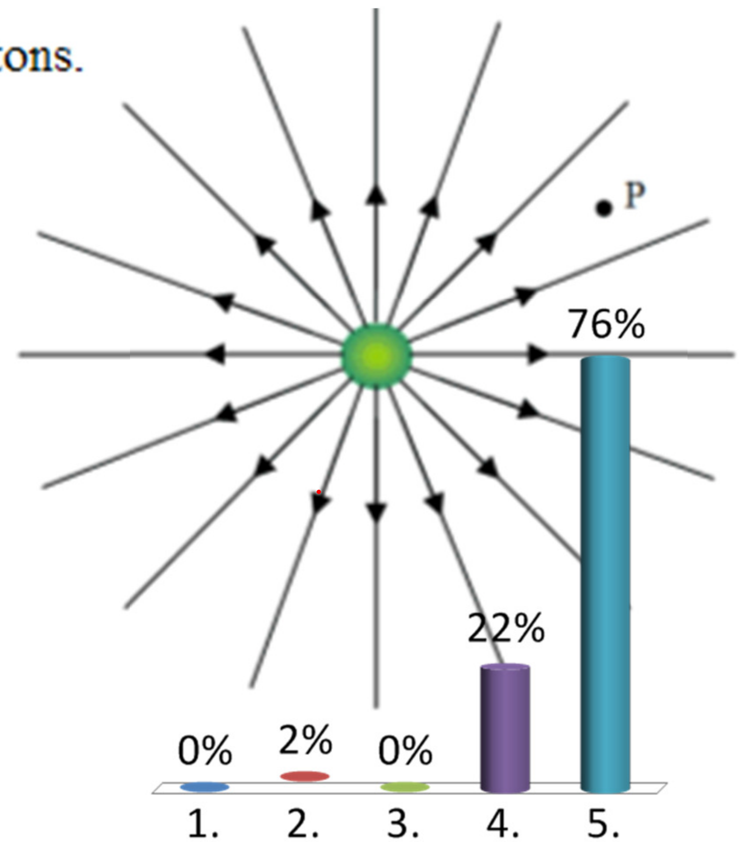
0

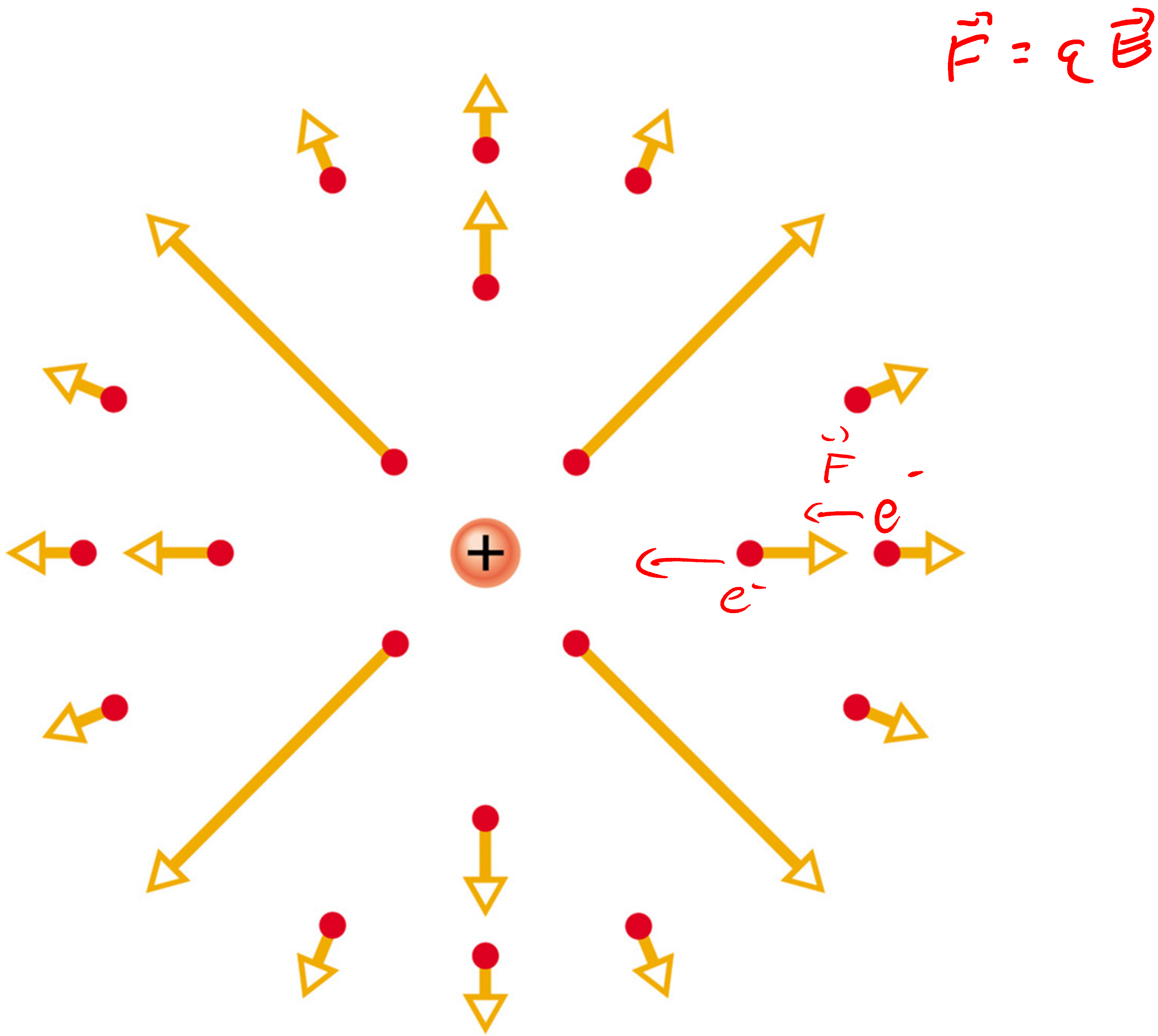
An electron is placed at the point P and released from rest in the electric field shown below. Which of the following vectors represents the direction of the force, if any, on the electron?

1. The electric force will be zero newtons.
2. 
3. 
4. 
5. 

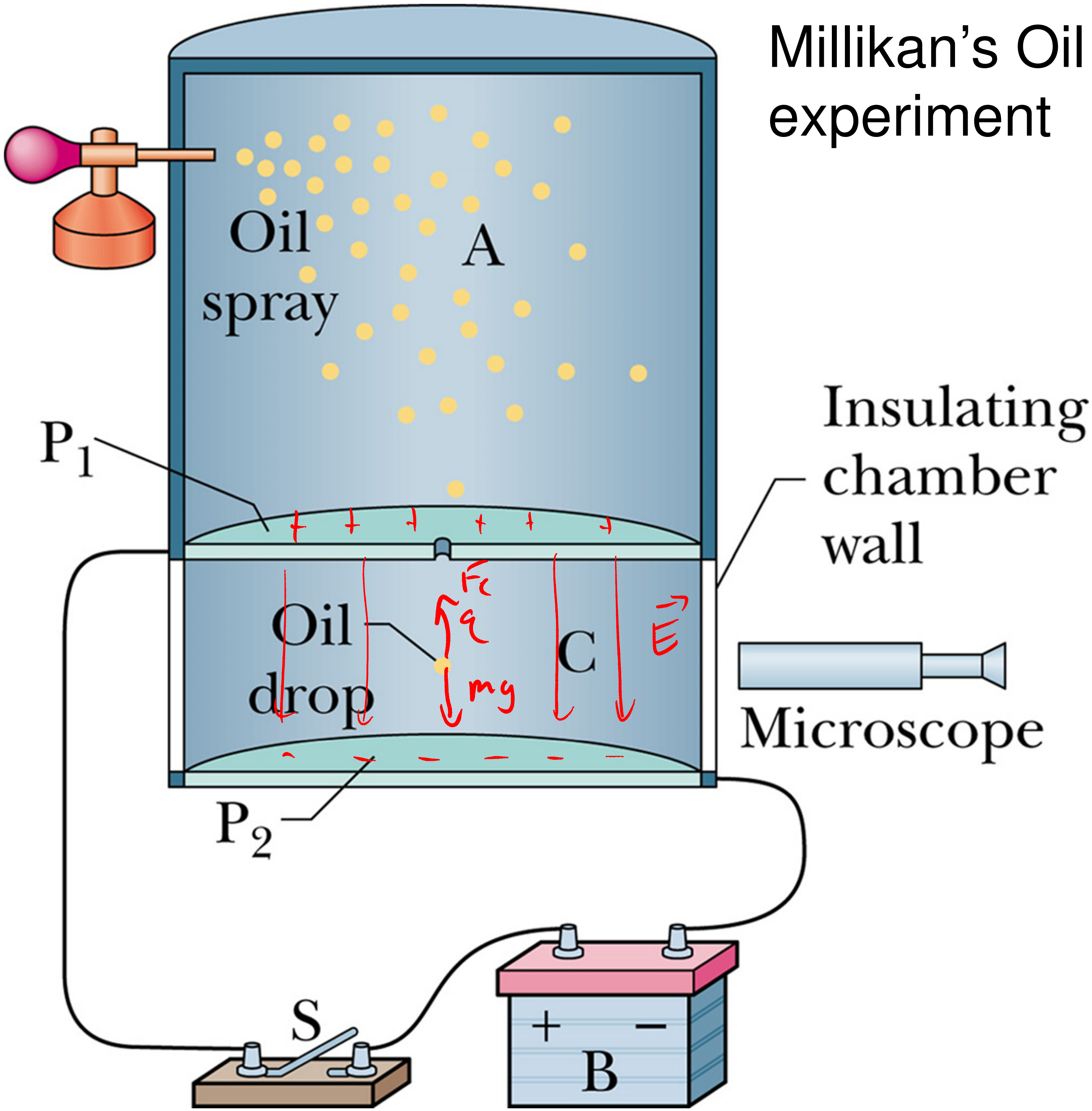


0

Fig. 22-4



Millikan's Oil Drop experiment

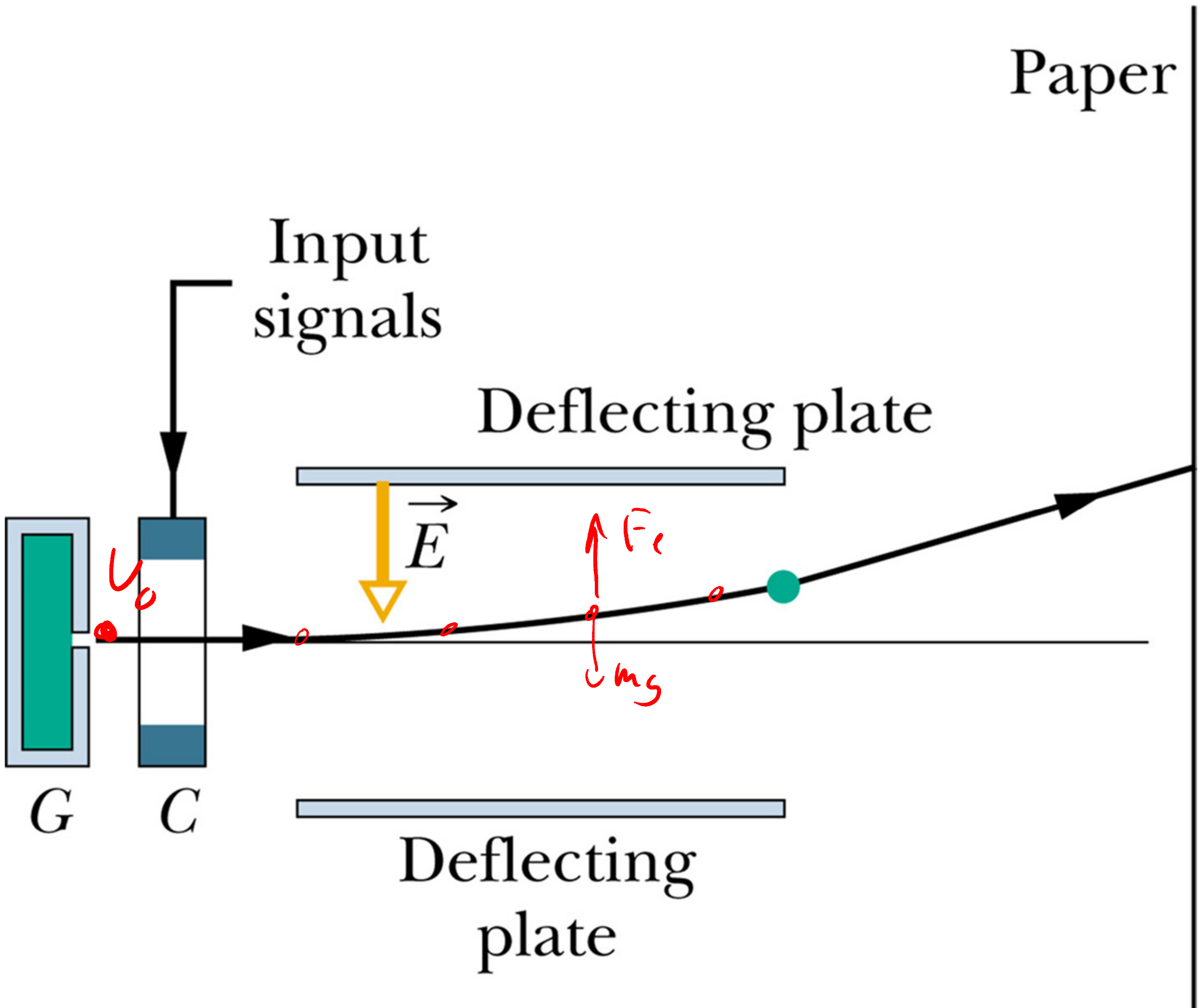


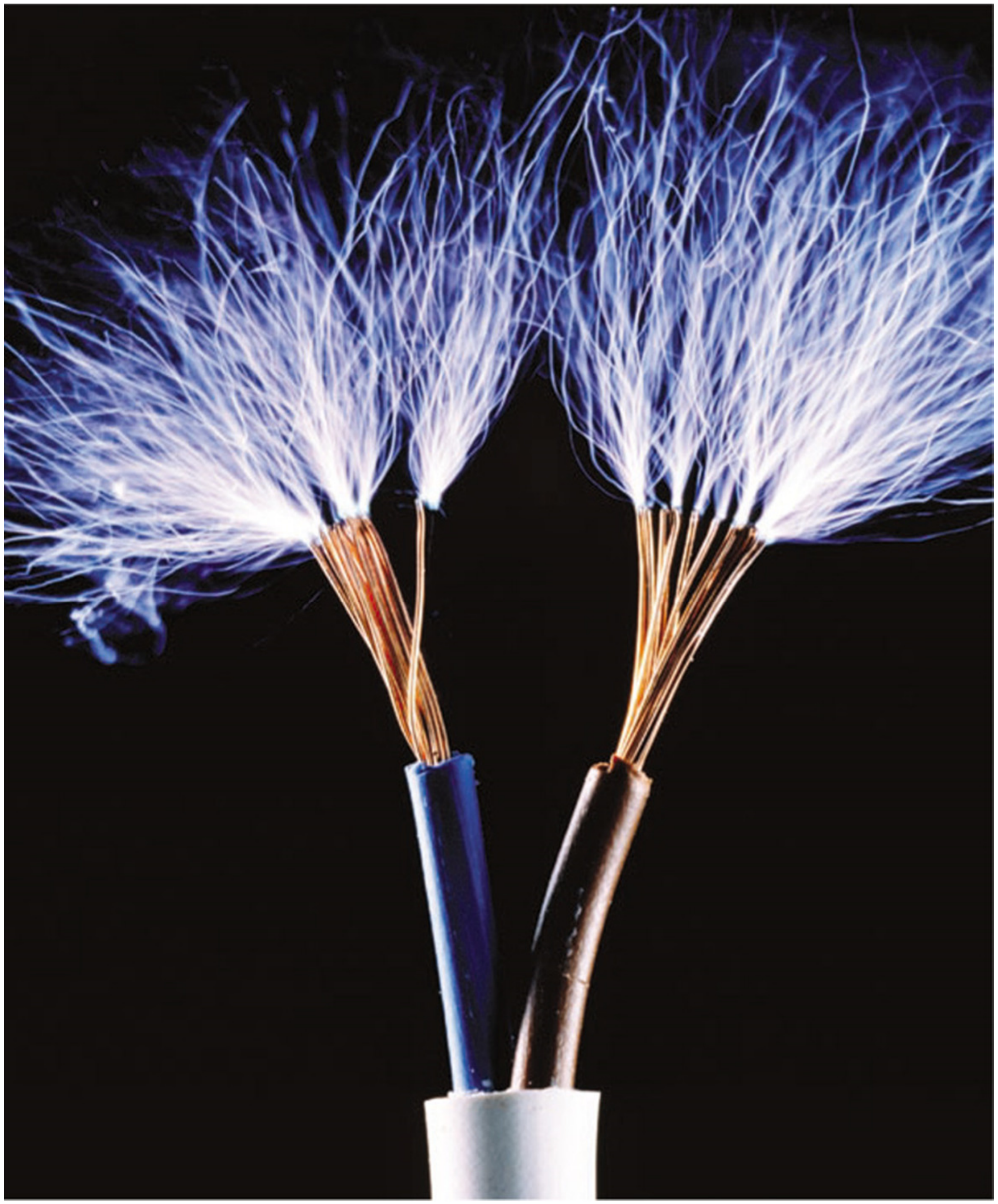
$\vec{F}_e = \vec{E} \cdot q$

$q = n\ e\text{'s}$

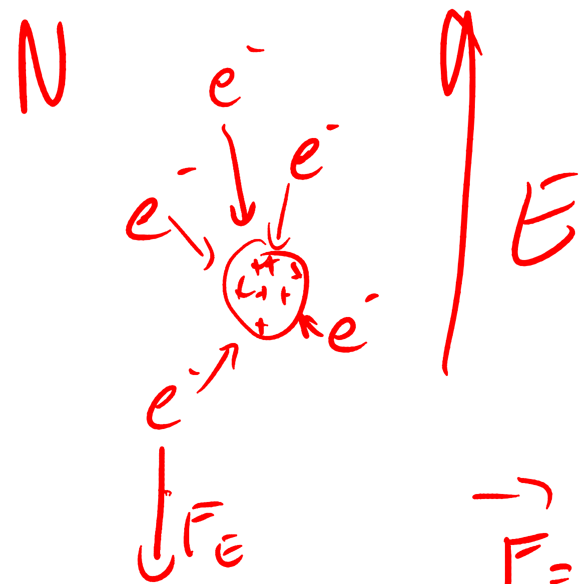
Inkjet printer

$\vec{F}_{net} = ma$ (y)





"Dielectric Breakdown"



$\vec{F} = \vec{E} \cdot q$

$\vec{E}$ of 3×10^6 V/m

breaks air

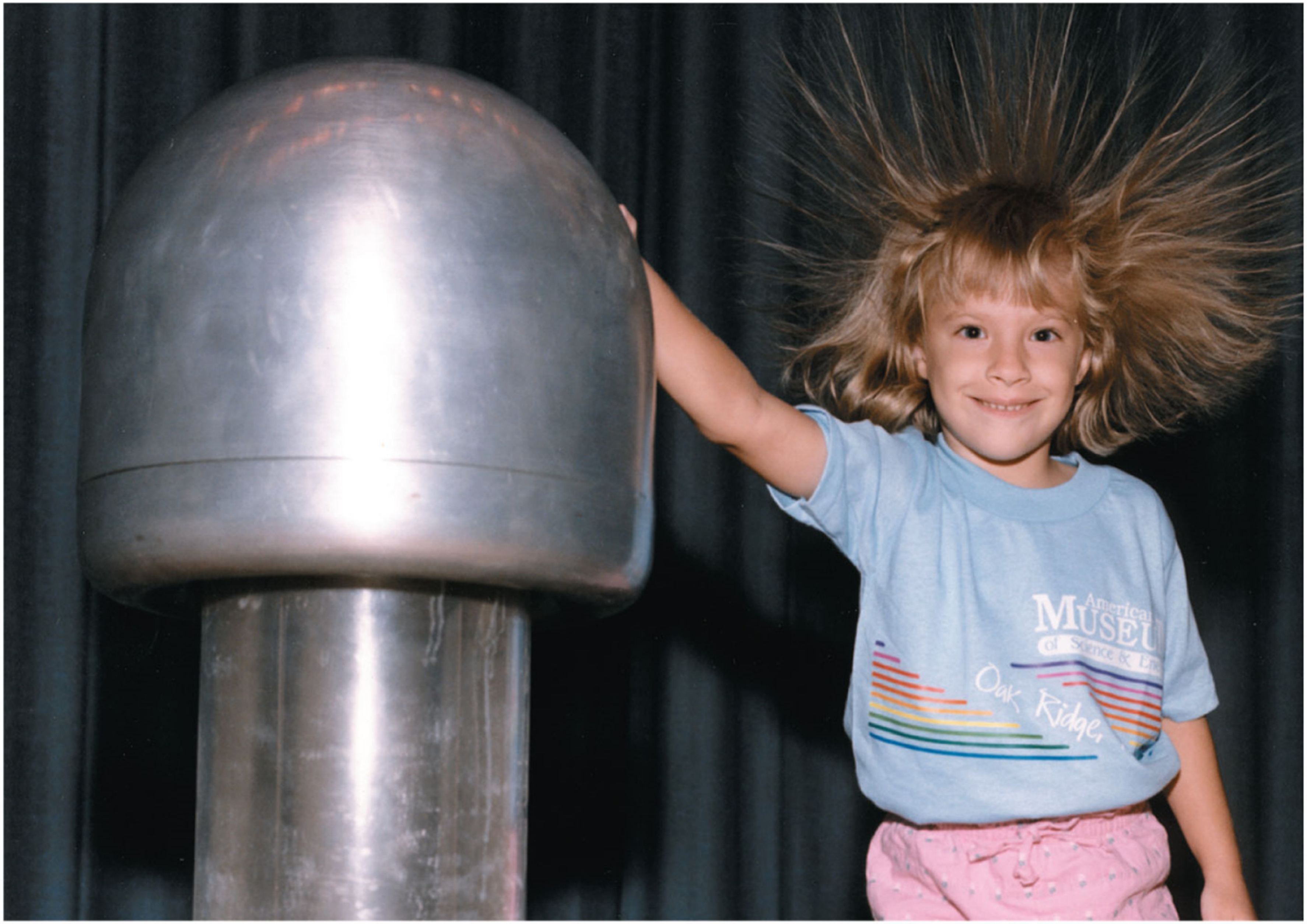
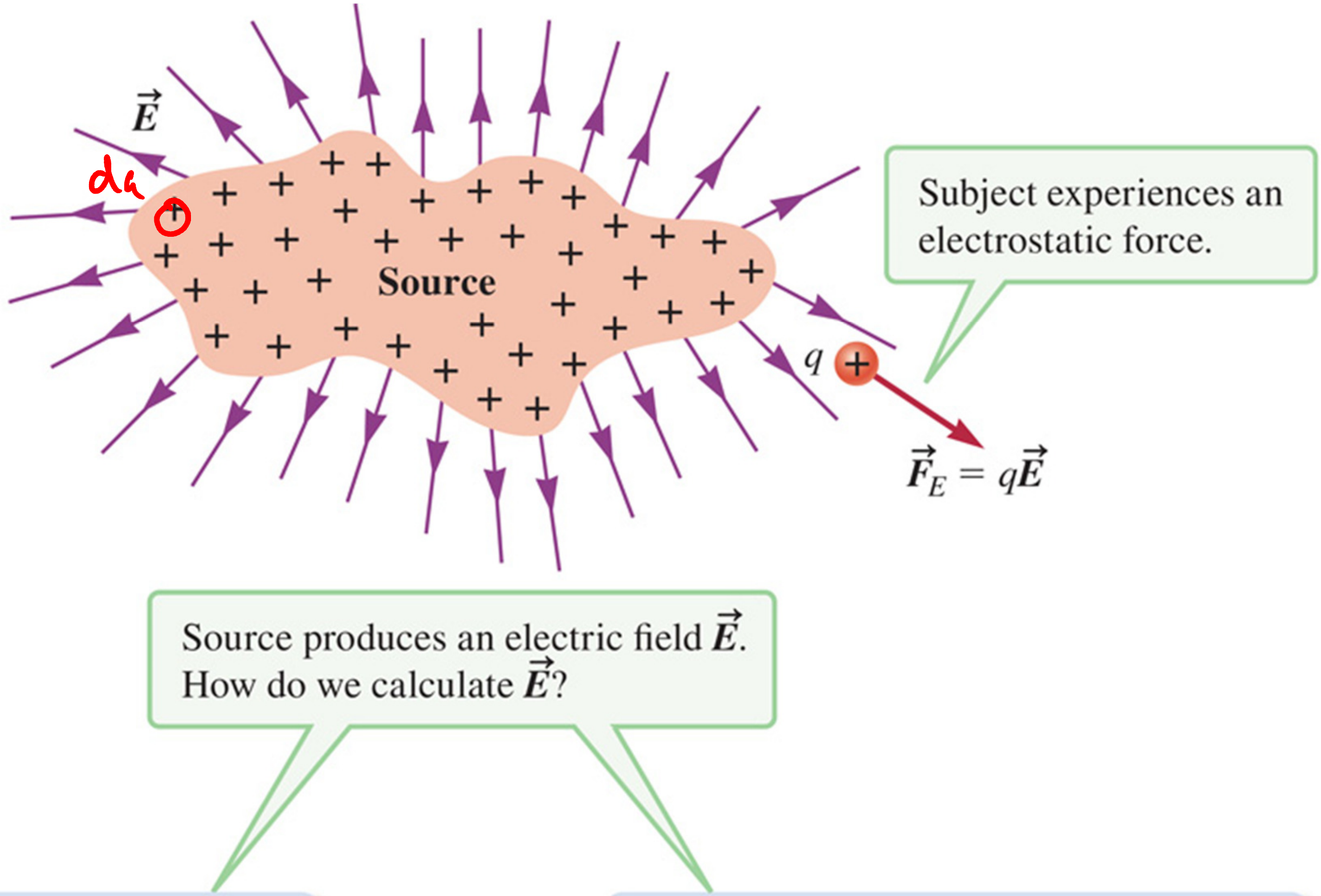

Oak Ridge,

Figure 25.1

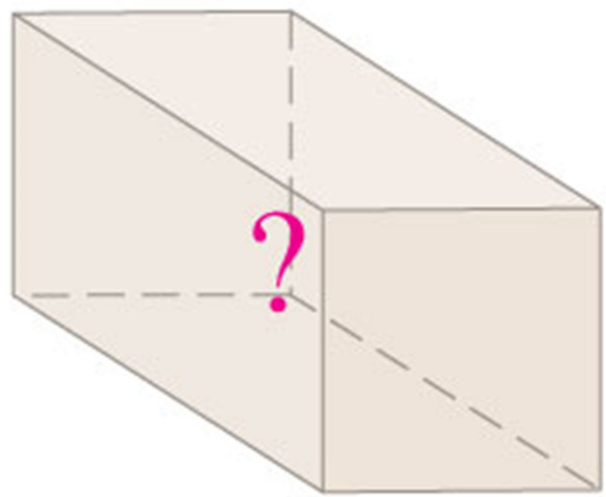
$dE = \frac{k\,dq}{r^2}$



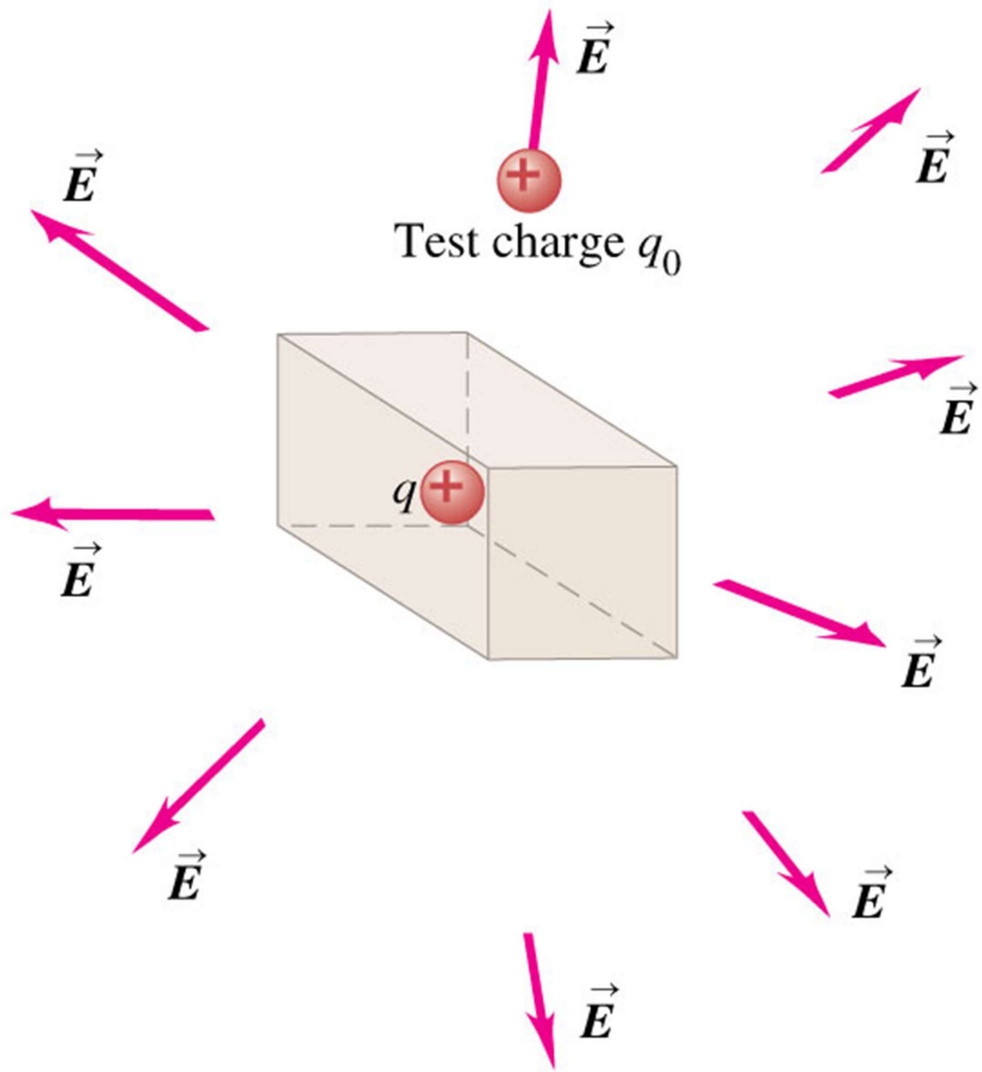
Brute force method: Chapter 24
- Divide source into small pieces.
- Treat each piece as a charged particle.
- Add/integrate electric field due to each piece using Coulomb's law.

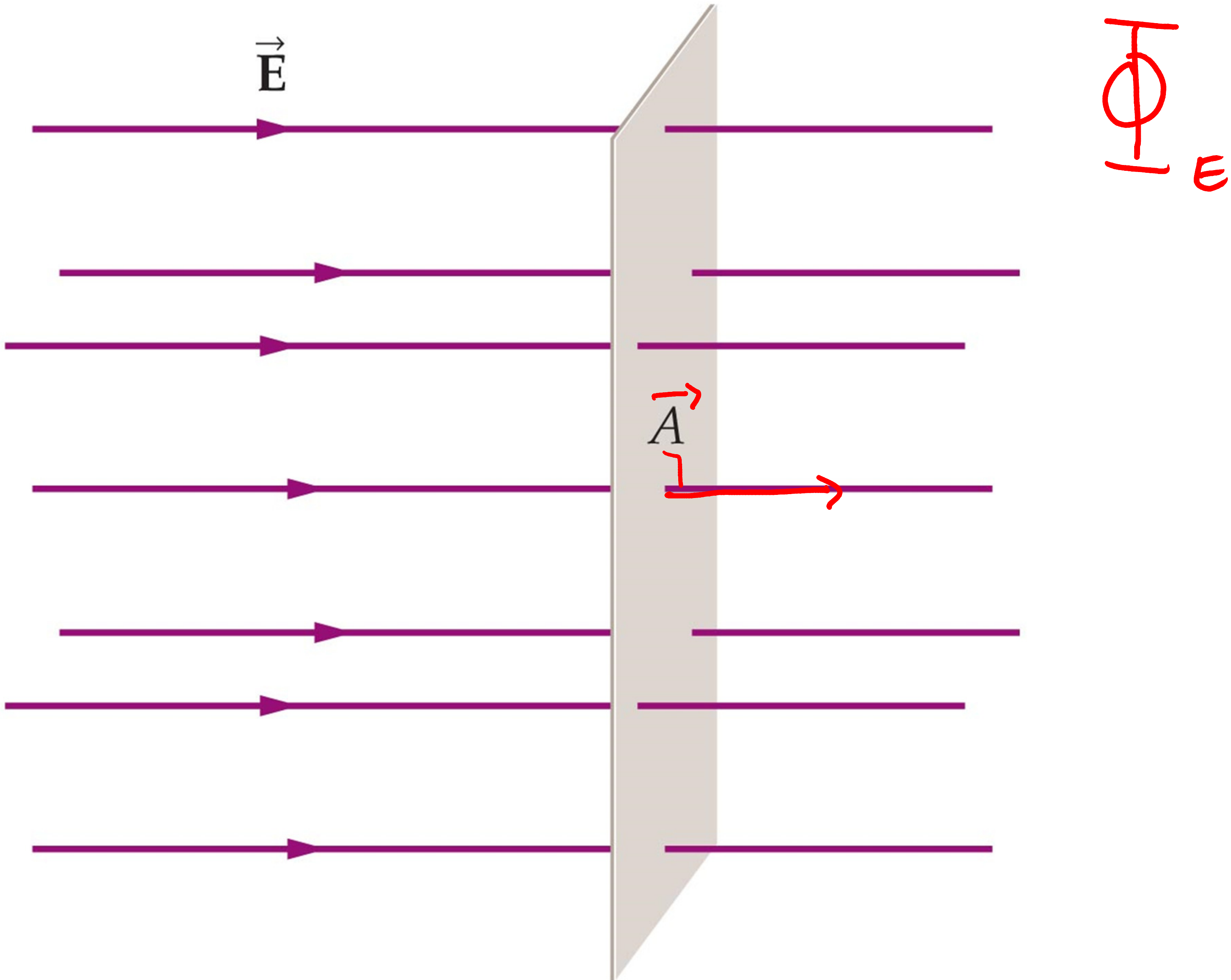
Use Gauss's law: Chapter 25
- General relationship between charge and field line concentration.
- Very easy to use if source is symmetric.
- One of the four fundamental equations of electricity and magnetism.

(a) A box containing an unknown amount of charge

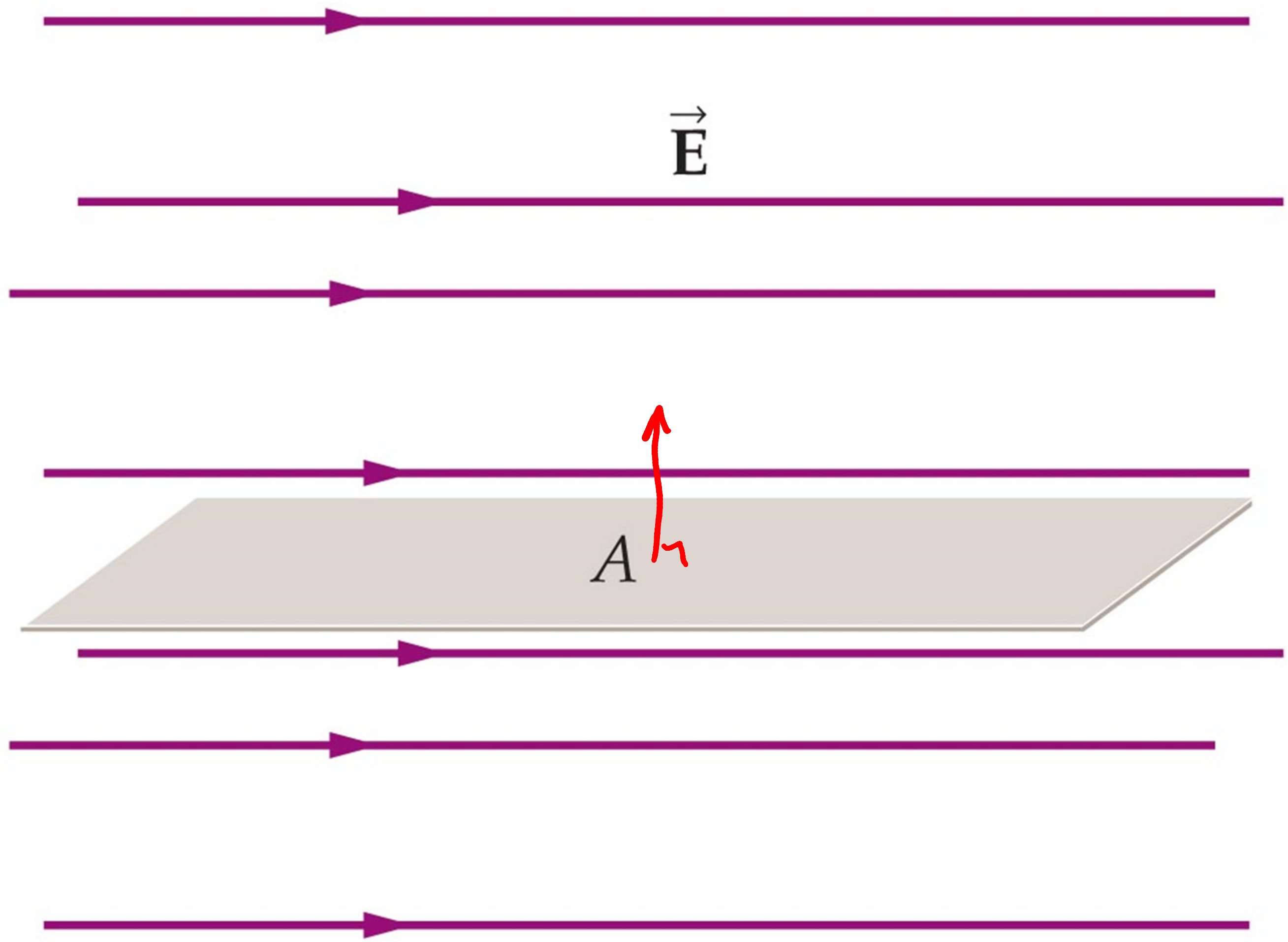


(b) Using a test charge outside the box to probe the amount of charge inside the box

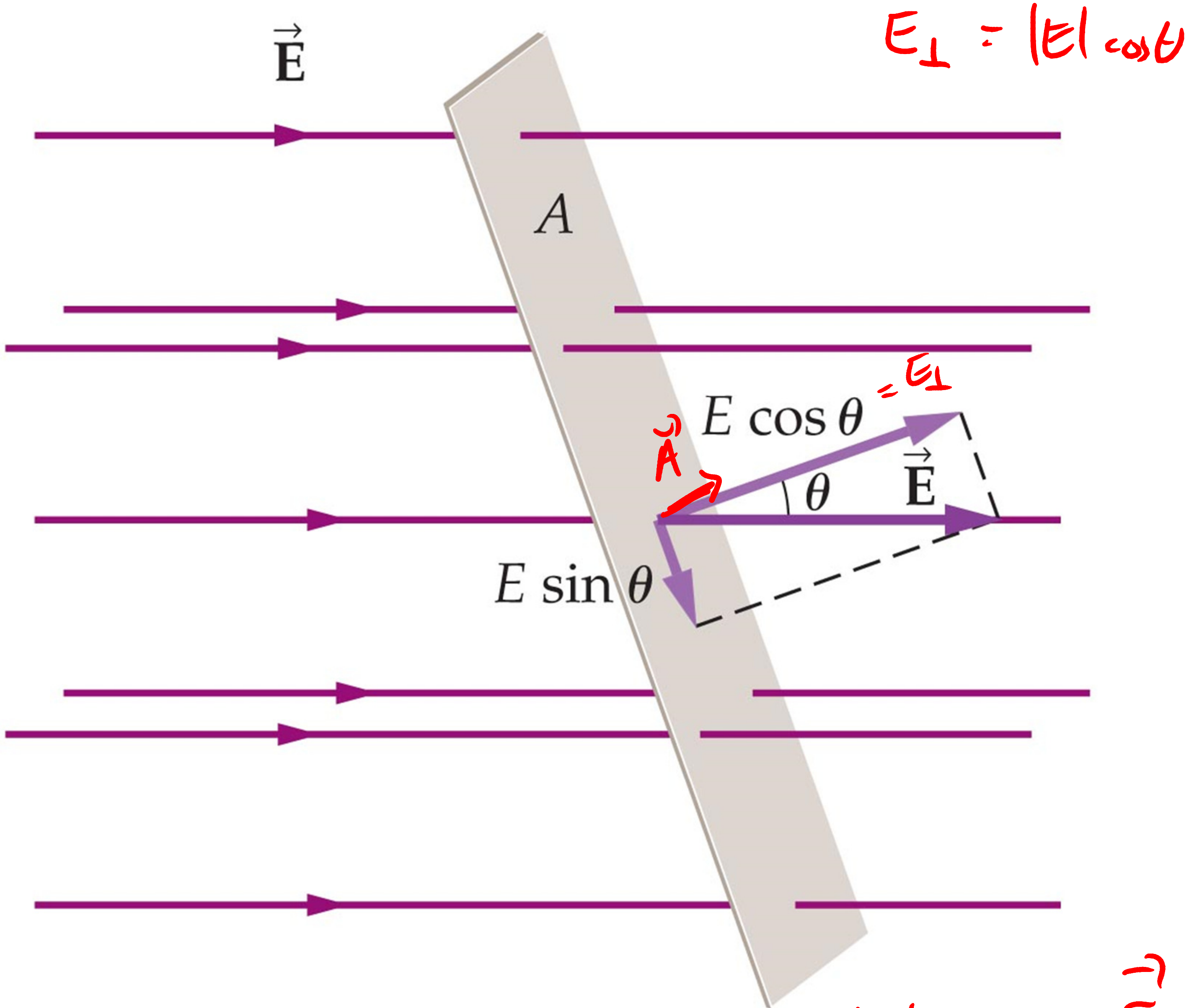




(a) Electric flux = EA = Φ_E

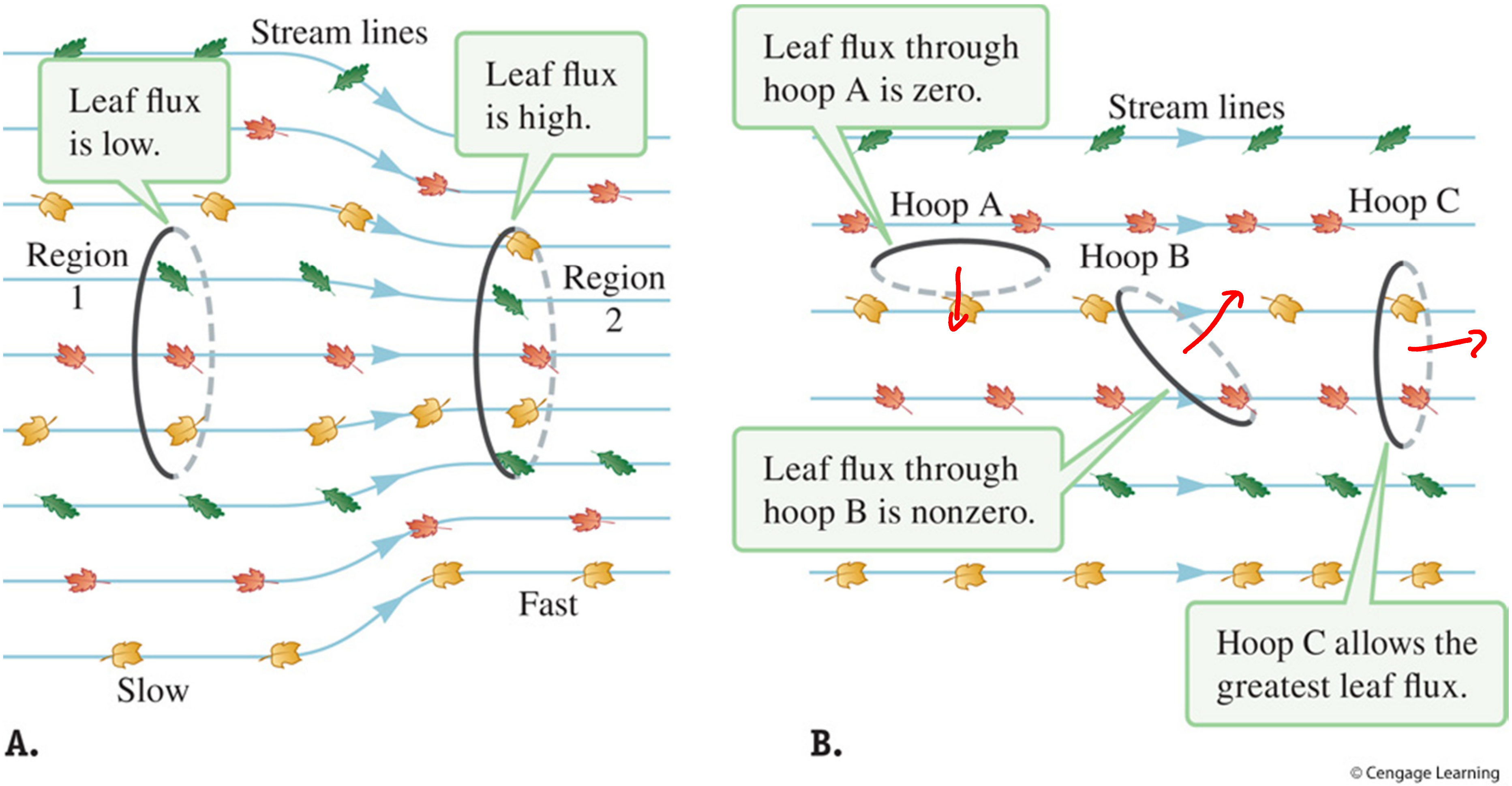


(b) Electric flux = 0



(c) Electric flux = $(E\cos\theta)A$ $= |E||A|\cos\theta = \vec{E}\cdot\vec{A}$

Figure 25.6


Stream lines
Leaf flux is low.
Leaf flux is high.
Region 1
Region 2
Slow
Fast
A.
Leaf flux through hoop A is zero.
Stream lines
Hoop A
Hoop B
Hoop C
Leaf flux through hoop B is nonzero.
Hoop C allows the greatest leaf flux.
B.
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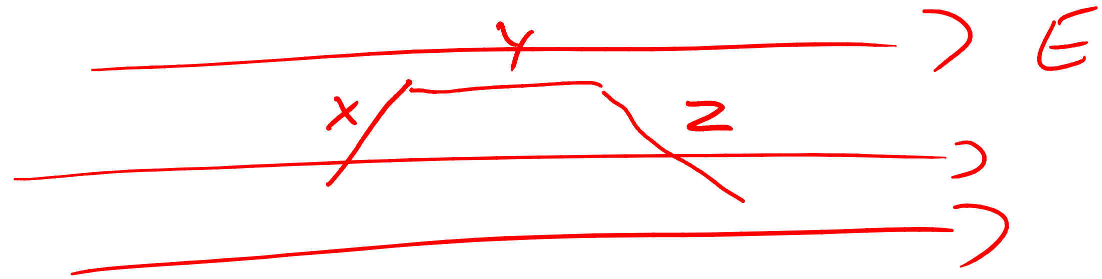
Worksheet with folded paper…



Worksheet with cube…