Lecture 07: 02/06/2024

- Announcements
  There are only 9 problems tonight (I vanished one!)

- Last Time
  - Electric field
    More examples of vector addition for E-field
    Electric field lines

- Today
  Electric field lines
  Flux
  Gauss's law

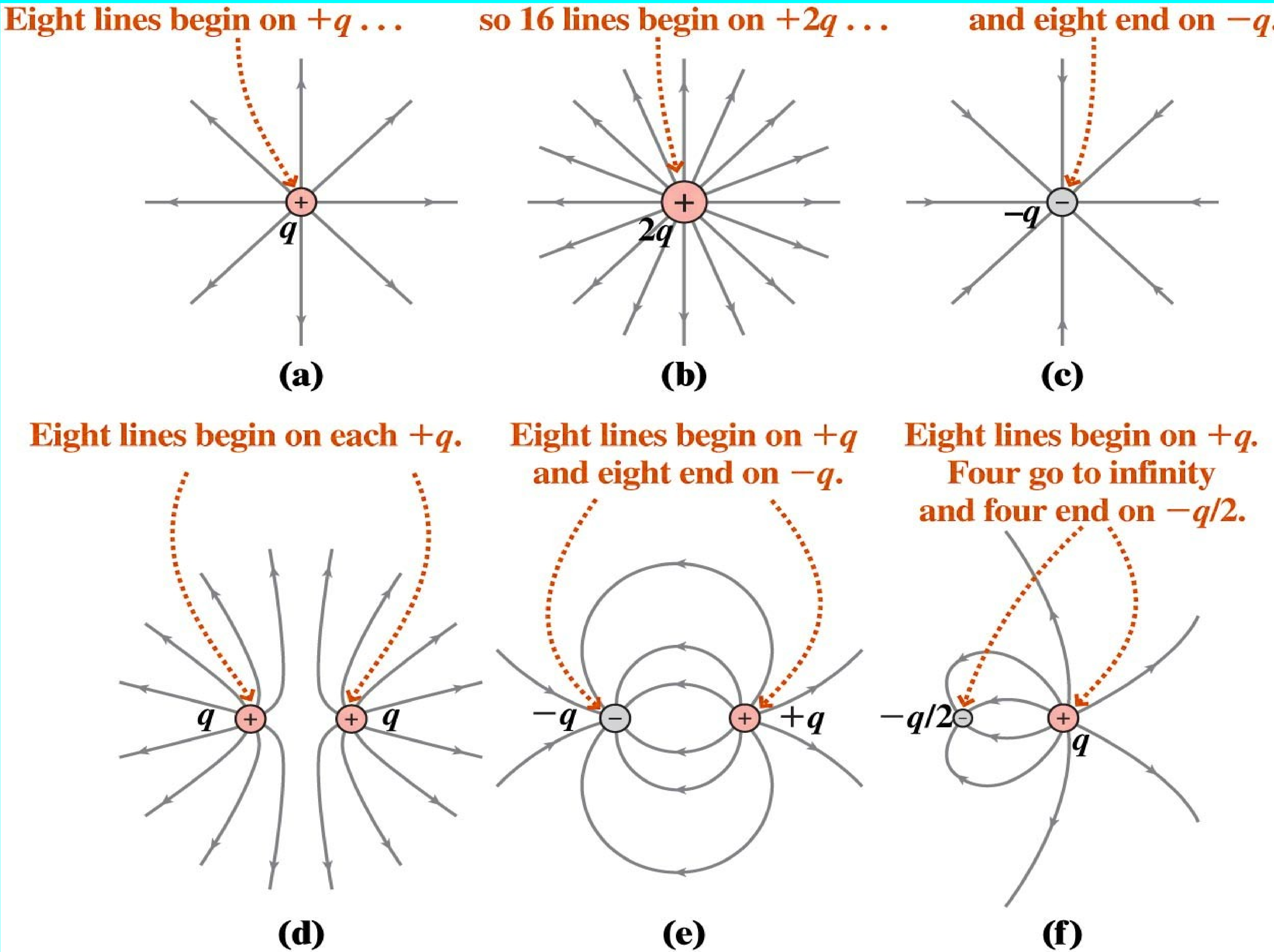
SCHEDULE

#	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	

Electric Field Lines

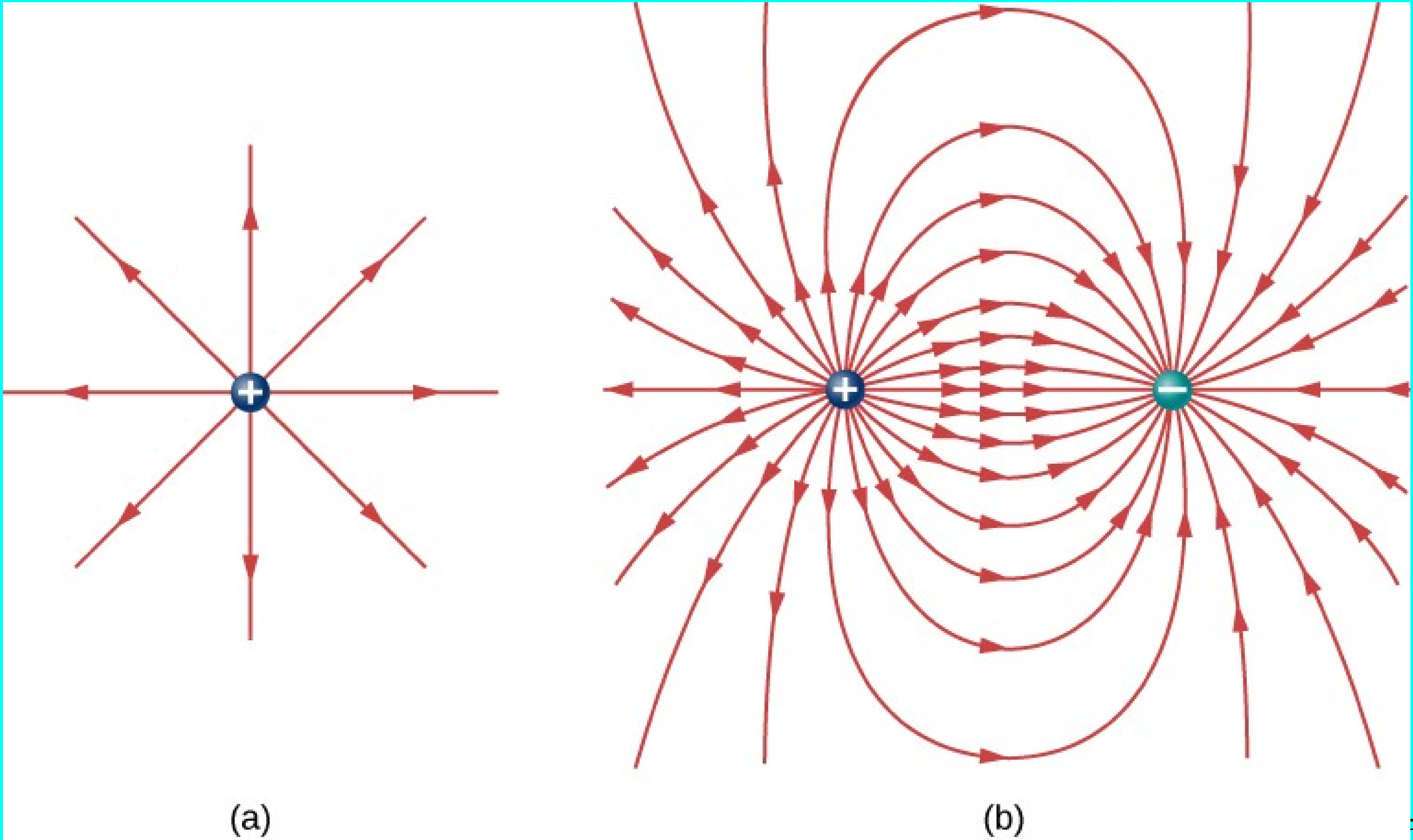
- A way of getting intuition for the fields caused by a few charges (without calculating)
- Helpful for thinking about "flux"

- 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 field
- Electric field lines do not cross

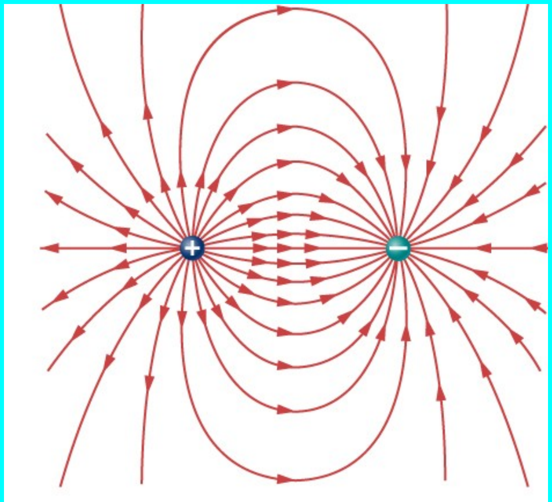


Eight lines begin on +q . . .
so 16 lines begin on +2q . . .
and eight end on −q.
q
2q
−q
(a)
(b)
(c)
Eight lines begin on each +q.
Eight lines begin on +q and eight end on −q.
Eight lines begin on +q. Four go to infinity and four end on −q/2.
q
q
−q
+q
−q/2
q
(d)
(e)
(f)

Field line views



Field line views



(b)

academo_field_line_sim

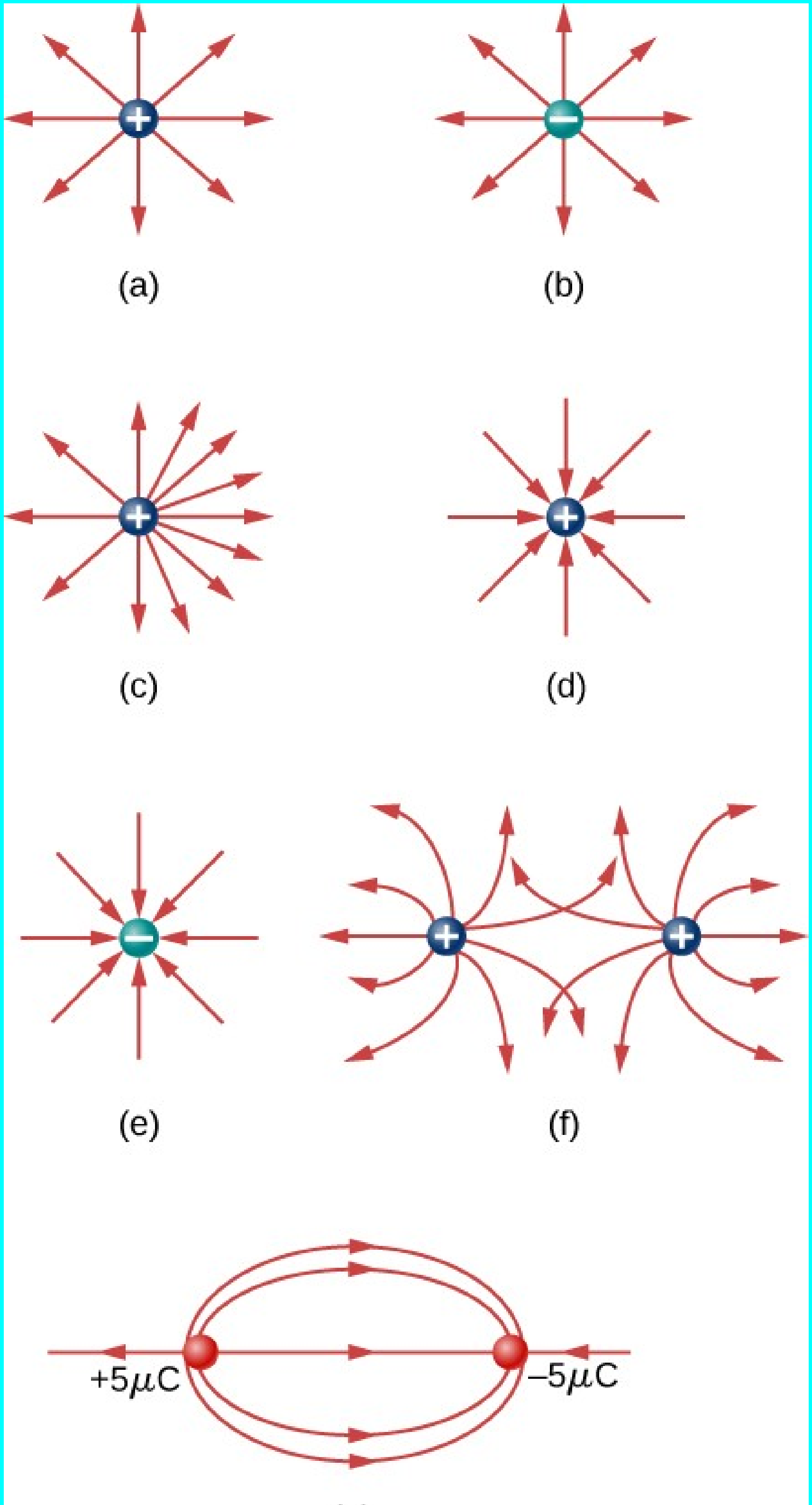
https://academo.org/demos/electric-field-line-simulator/

icphysweb_field_line_simulator

https://icphysweb.z13.web.core.windows.net/simulation.html

electric_field_hockey

https://phet.colorado.edu/sims/cheerpj/electric-hockey/latest/electric-hockey.html?simulation=electric-hockey



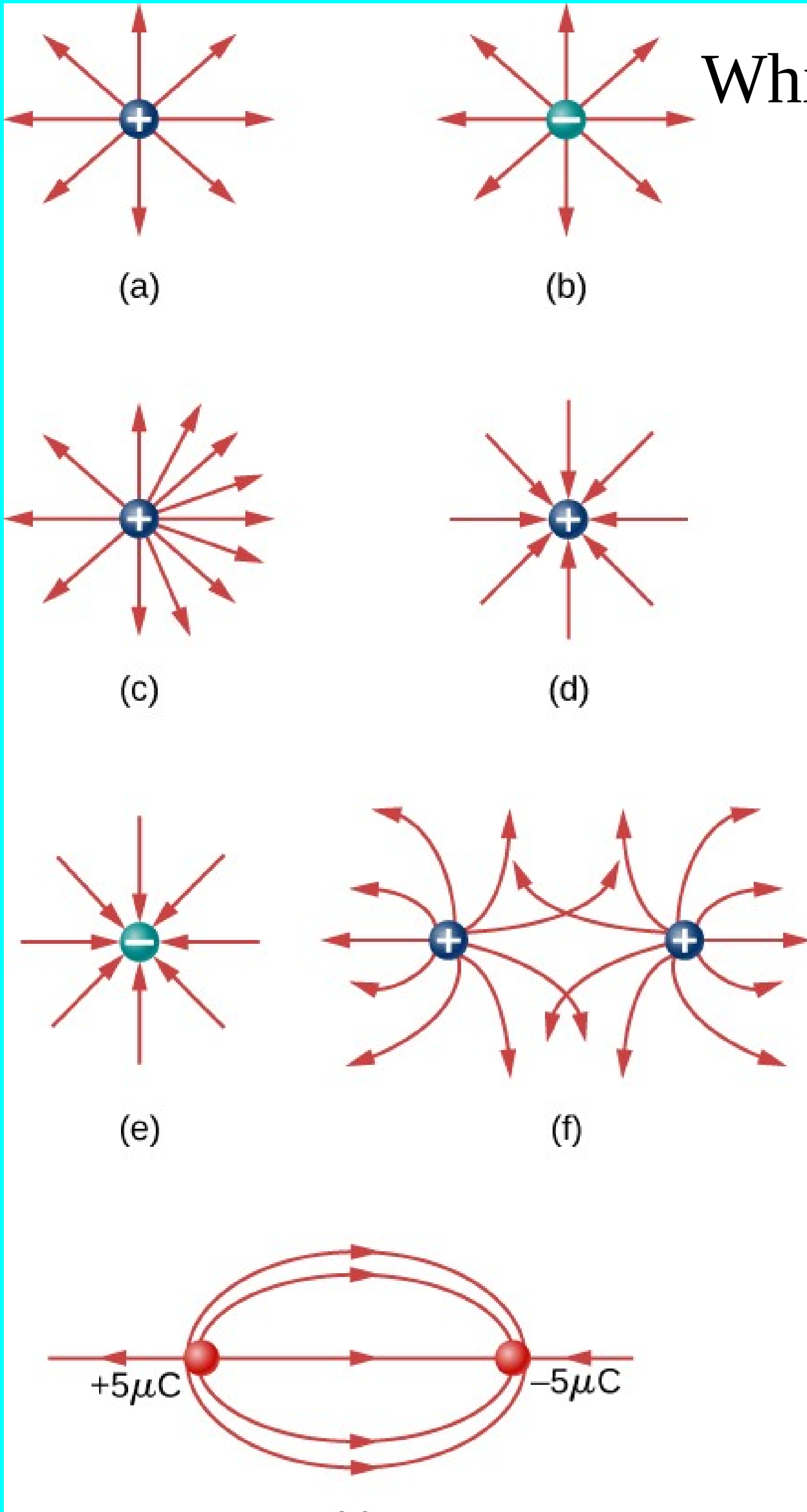
Positive charges “emit” field lines.

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



Which of these sketches are possibly correct?

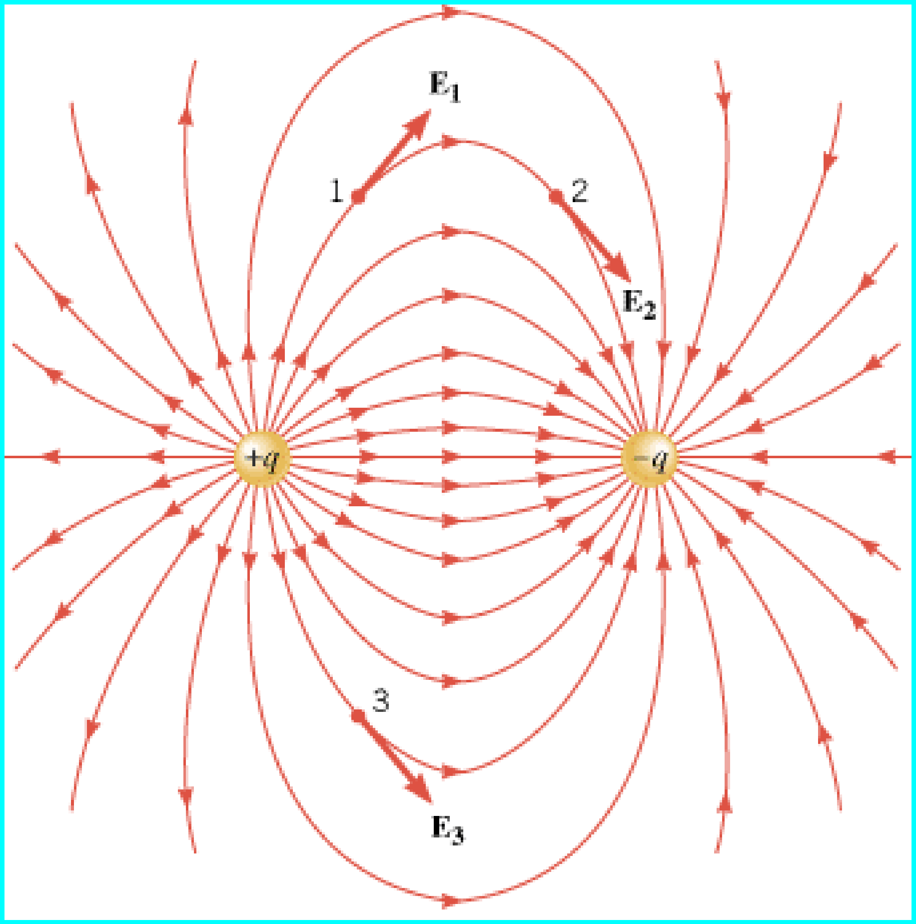
(A) 'a' and 'b'

(B) 'a' and 'c' and 'e'

(C) 'b' and 'e' and 'f'

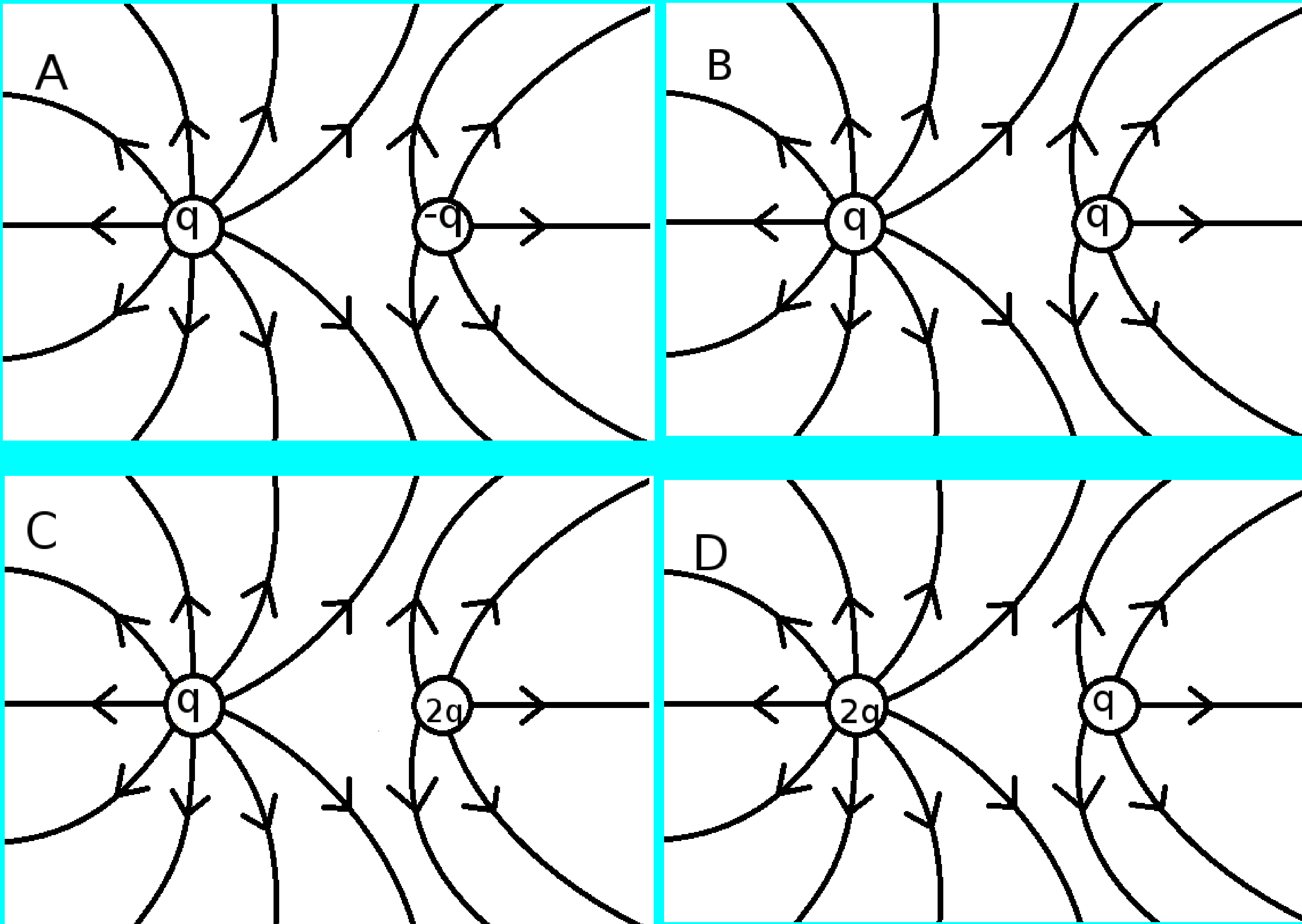
(D) 'a' and 'e' and 'f' and 'g'

(E) 'a' and 'e'



The tangent to an electric field line gives direction of field

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	$\vec{\mathbf{p}} = q\vec{\mathbf{d}}$

flux noun

Save Word

\ ˈfləks \

Definition of *flux* (Entry 1 of 2)

1 : a flowing of fluid from the body: such as

a : DIARRHEA

b : DYSENTERY

2 : a continuous moving on or passing by (as of a stream)

3 : a continued flow : FLOOD
// a *flux* of words

4 **a** : INFLUX

b : CHANGE, FLUCTUATION
// in a state of *flux*
// the *flux* following the death of the emperor

5 : a substance used to promote fusion (as of metals or minerals)

especially : one (such as rosin) applied to surfaces to be joined by soldering, brazing, or welding to clean and free them from oxide and promote their union

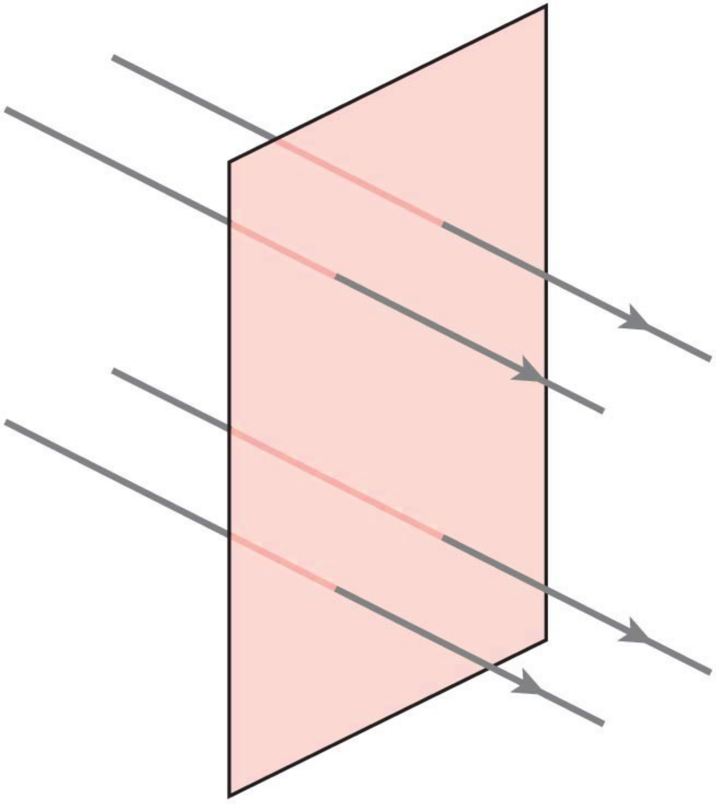
6 : the rate of transfer of fluid, particles, or energy across a given surface

Field

What is flux?

Flux – flow – like water through a hose, or electric field lines through a surface.

$$\Phi = \vec{E} \cdot \vec{A}$$

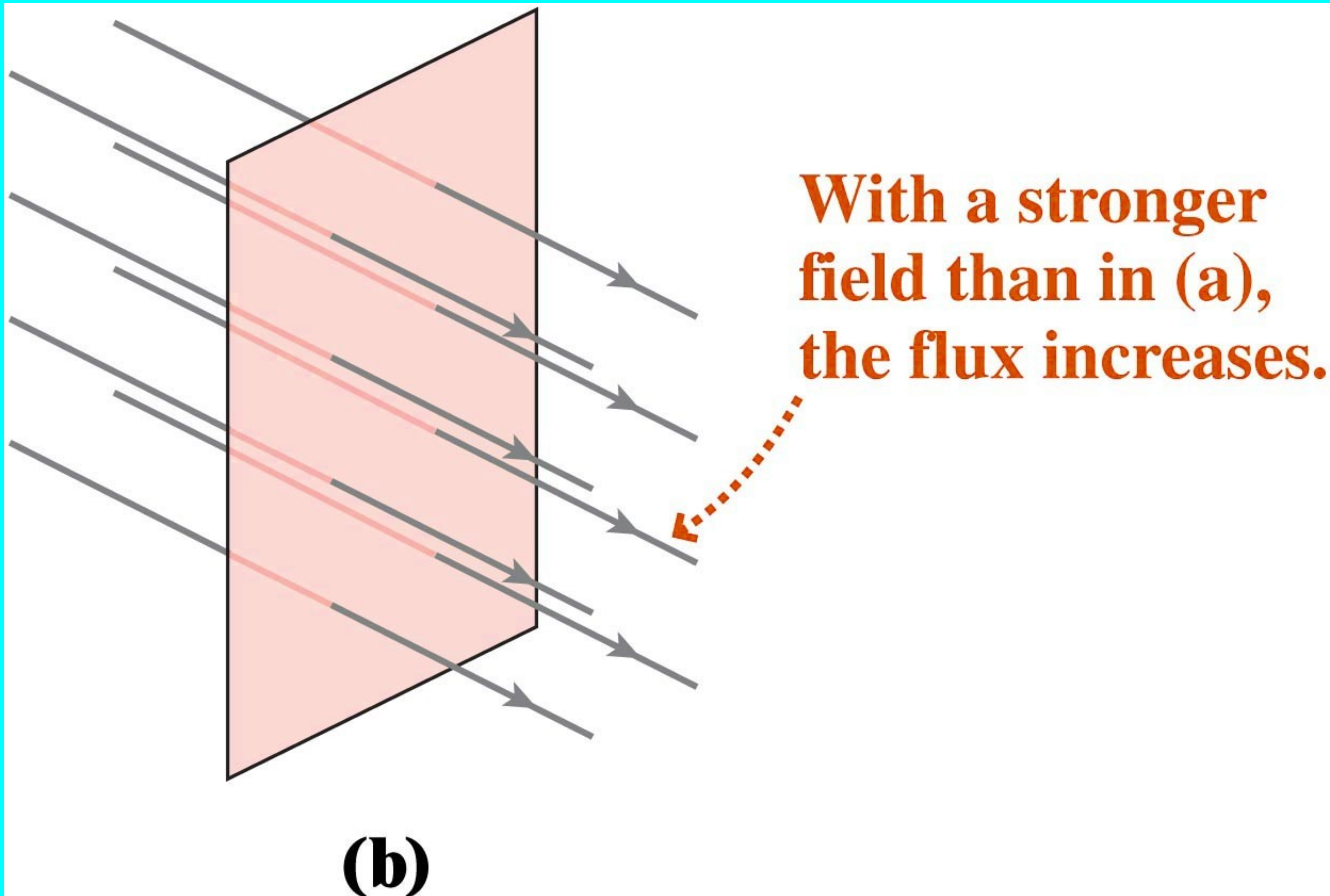


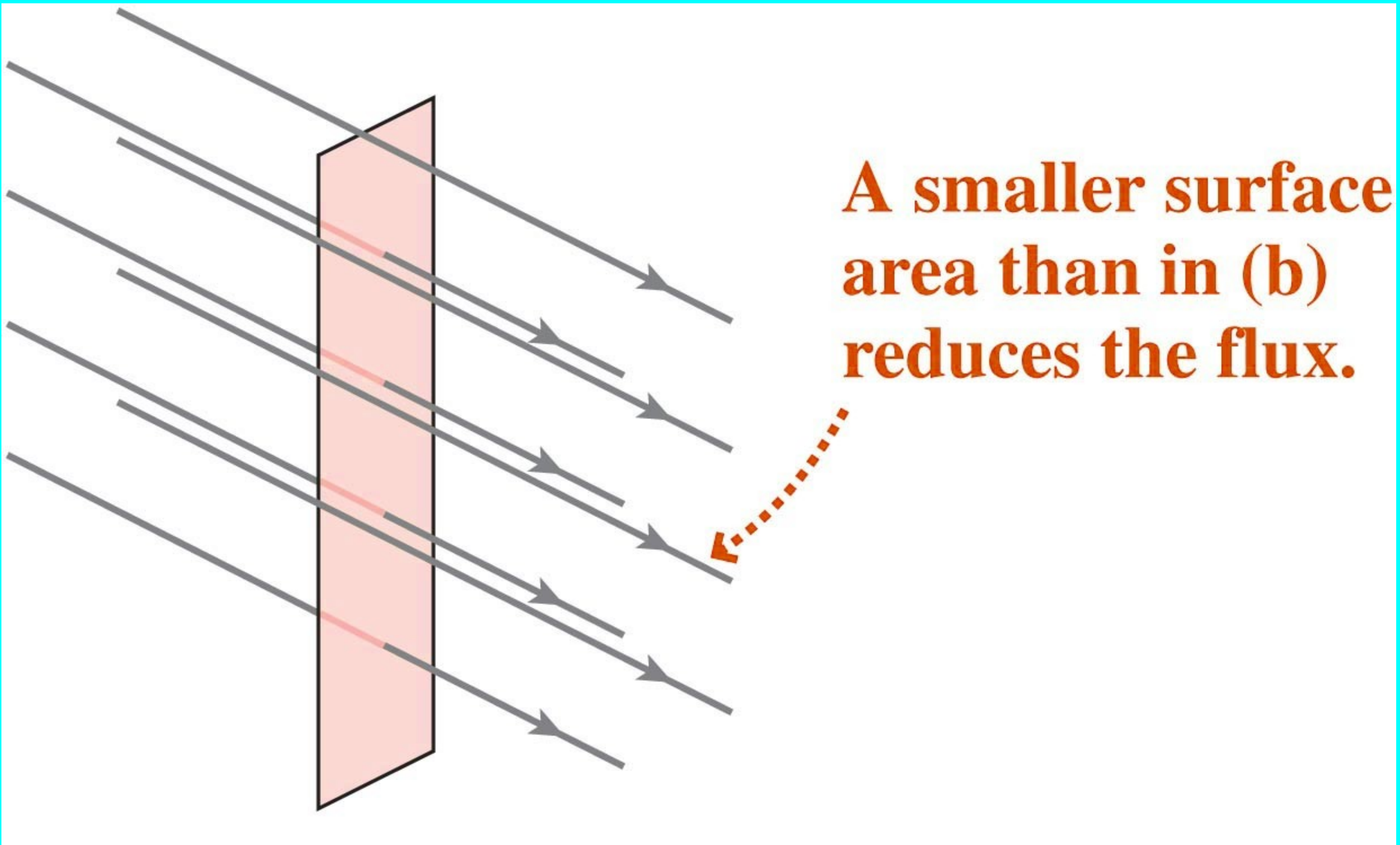
(a)

What is flux?

Flux – flow – like water through a hose, or electric field lines through a surface.

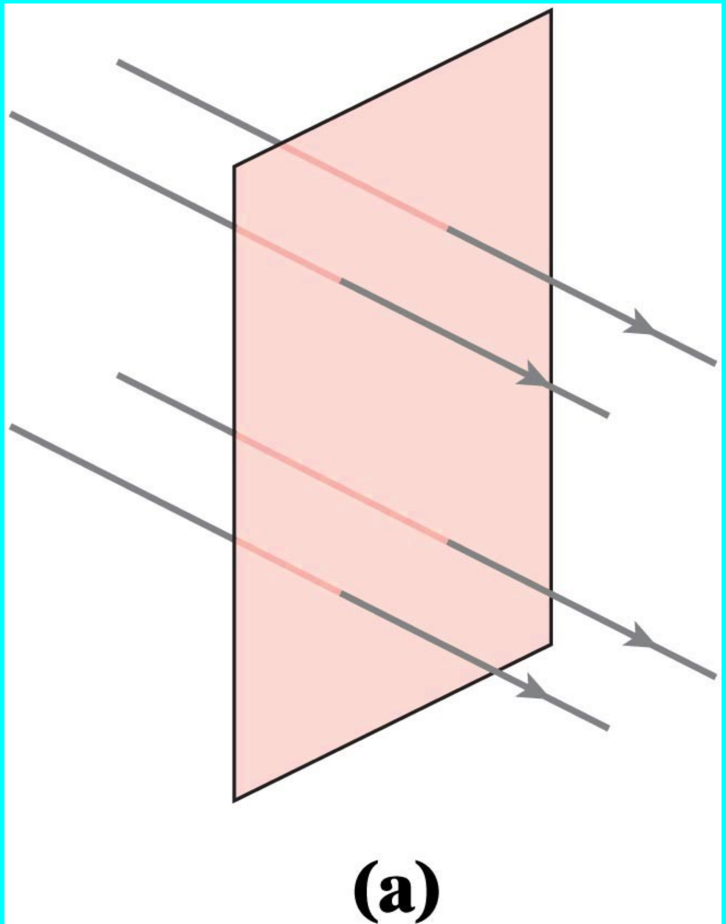
$$\Phi = \vec{E} \cdot \vec{A}$$





(c)

If $\vec{E} = 19\,\hat{i}$ N/C, What is Φ through this 2 x 3 m rectangle?



(A) $114\ \mathrm{N\,m^2/C}$

(B) $114\,\hat{i}\ \mathrm{N/C}$

(C) $114\ \mathrm{N/C}$

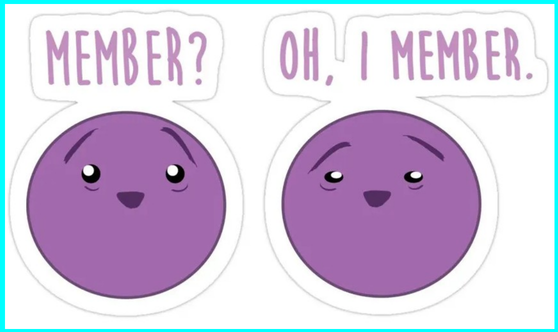
(D) $38\ \mathrm{N/C}$

(E) $19\,\hat{i}\ \mathrm{N/C}$

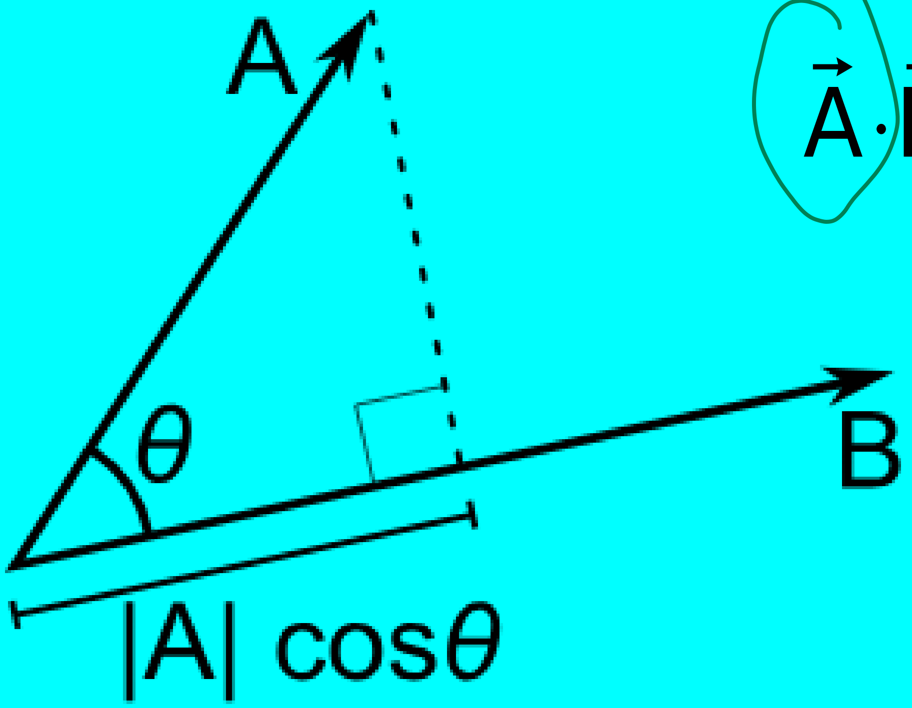
$$\Phi = \vec{E} \cdot \vec{A}$$

‘Member dot products?’

'Member dot products?'

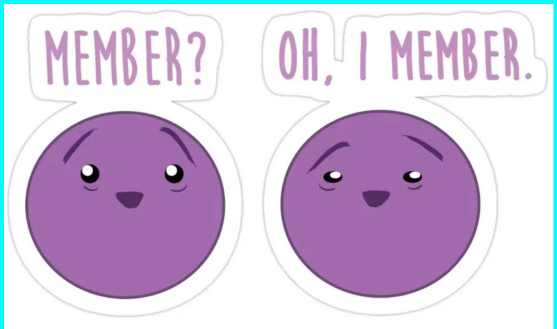


They convert two vectors to a scalar. They are zero when the vectors are perpendicular.



$$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos\theta$$

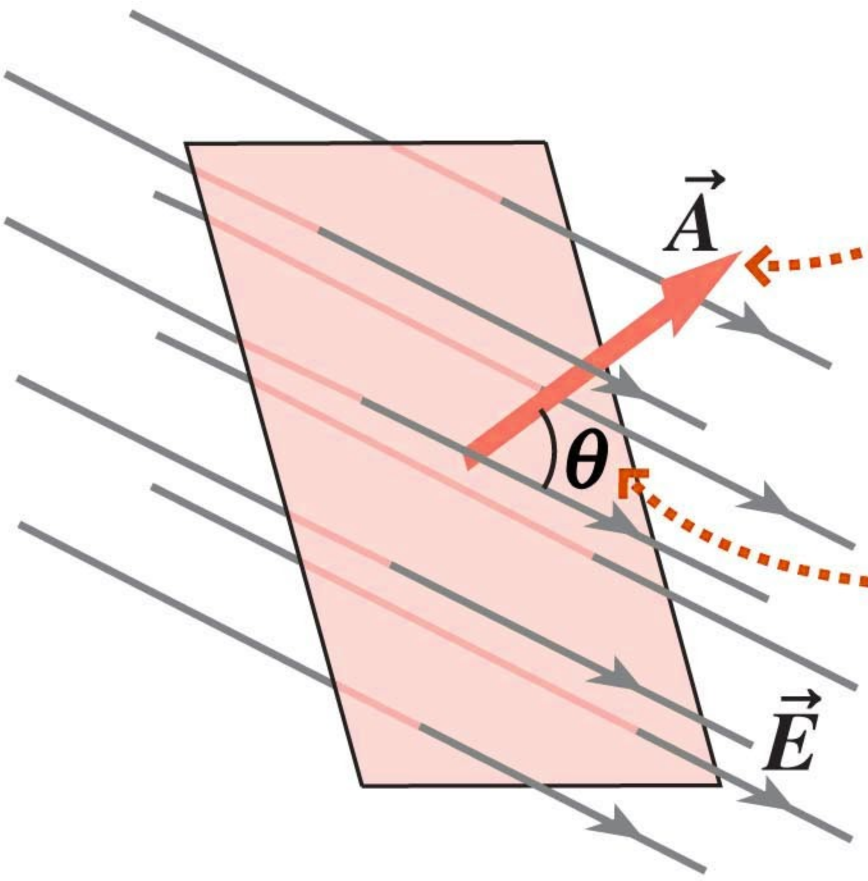
Work was a dot product!



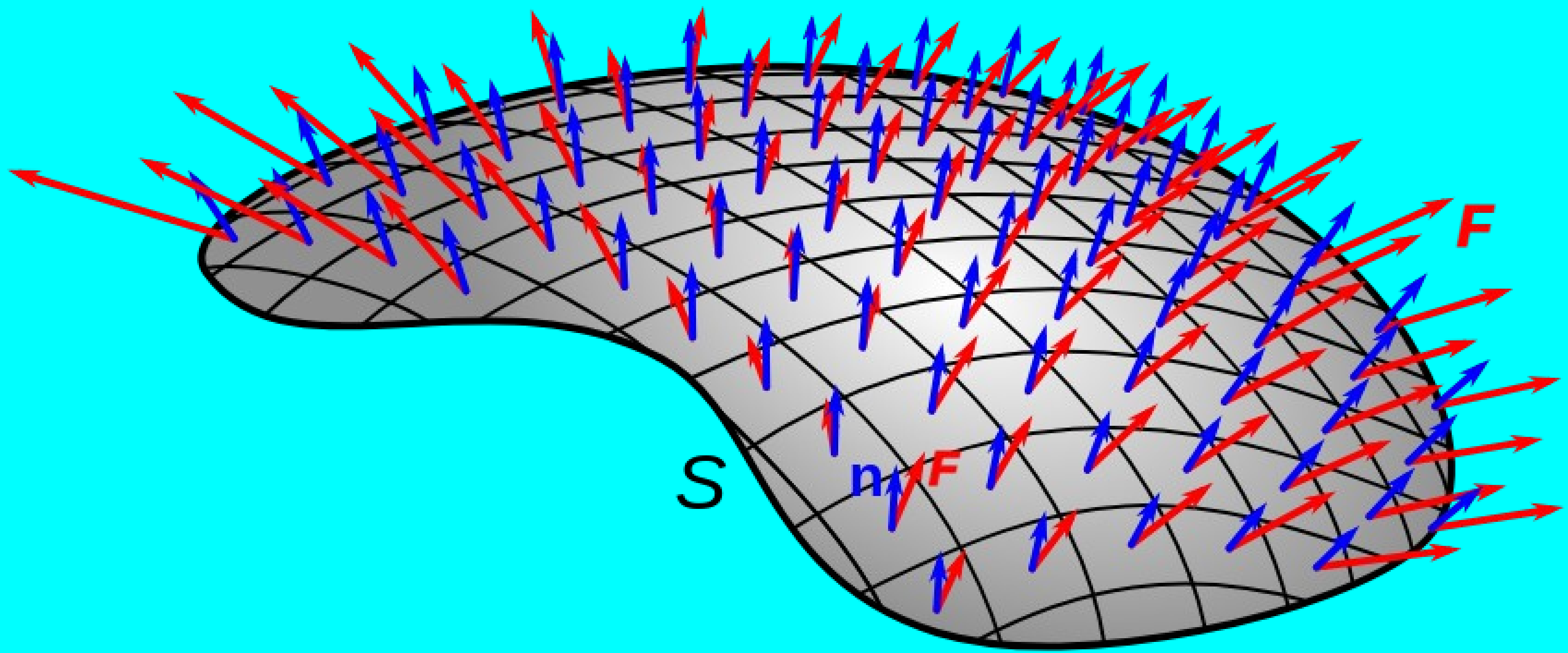
$$W = \vec{F} \cdot \Delta\vec{r} = |\vec{F}||\Delta\vec{r}|\cos\theta$$

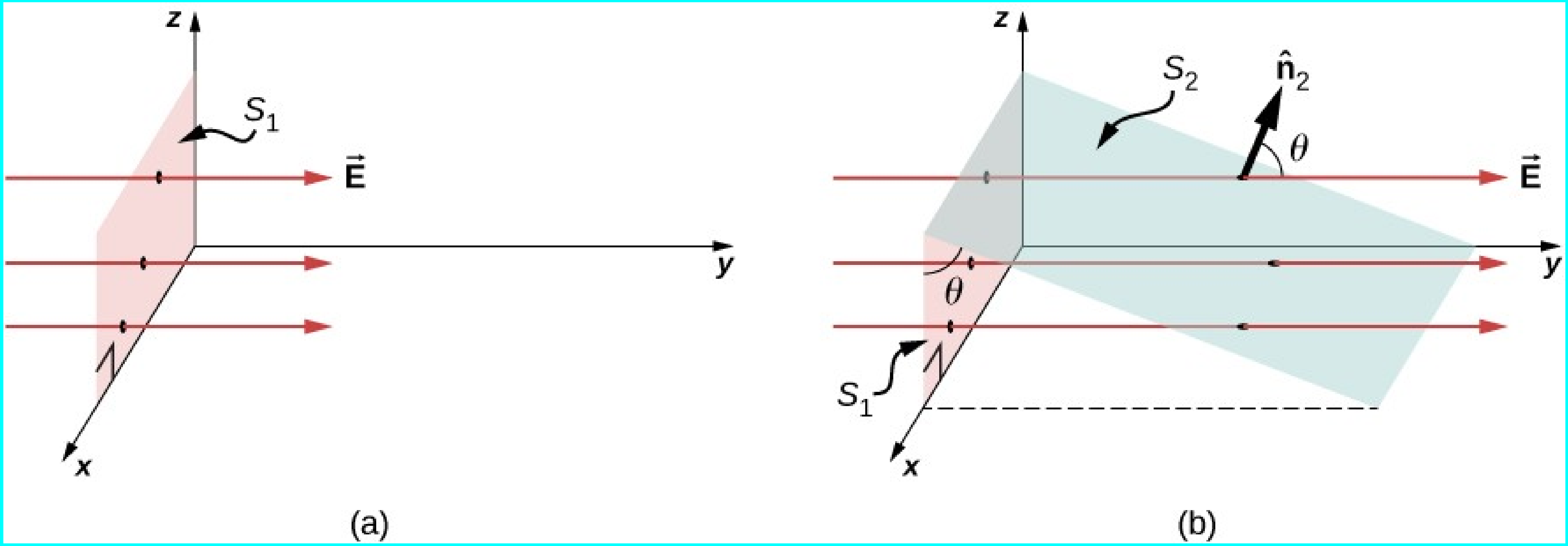
$$\Phi = \vec{E} \cdot \vec{A}$$

$$\Phi = \vec{E} \cdot \vec{A} = |\vec{E}||\vec{A}|\cos\theta$$



(d)


F
S
n
F


z
S_1
$\vec{E}$
y
x
(a)
z
S_2
$\hat{n}_2$
θ
$\vec{E}$
y
θ
S_1
x
(b)

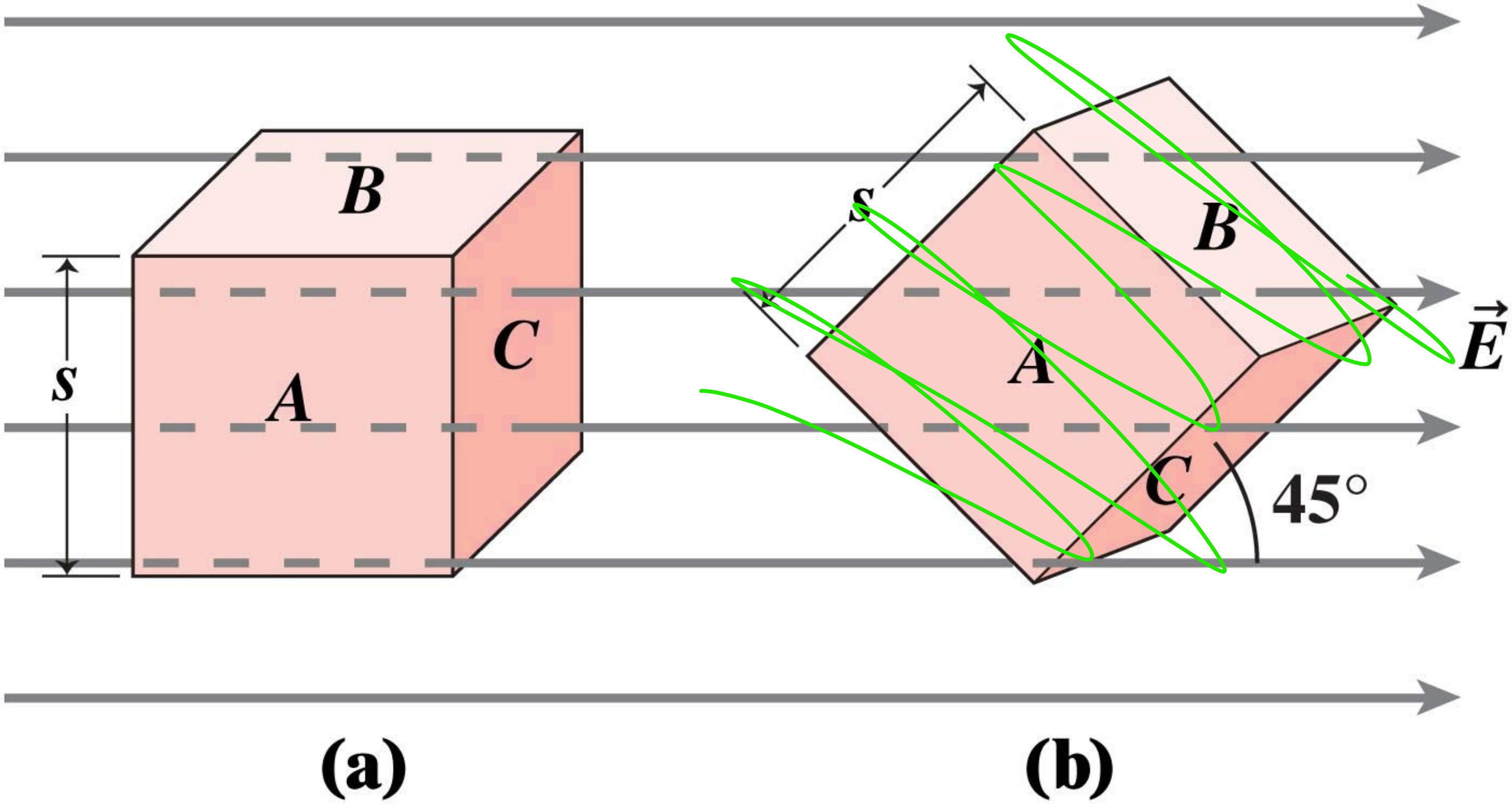
Flux – Cube "a"

Given E=10 N/C

s= 2 m

Flux through

C and A is?



(A) 10, 0 $N m^2/C$

(B) 4, 4 $N m^2/C$

(C) 0, 40 $N m^2/C$

(D) 28.8, 0 $N m^2/C$

(E) 40, 0 $N m^2/C$

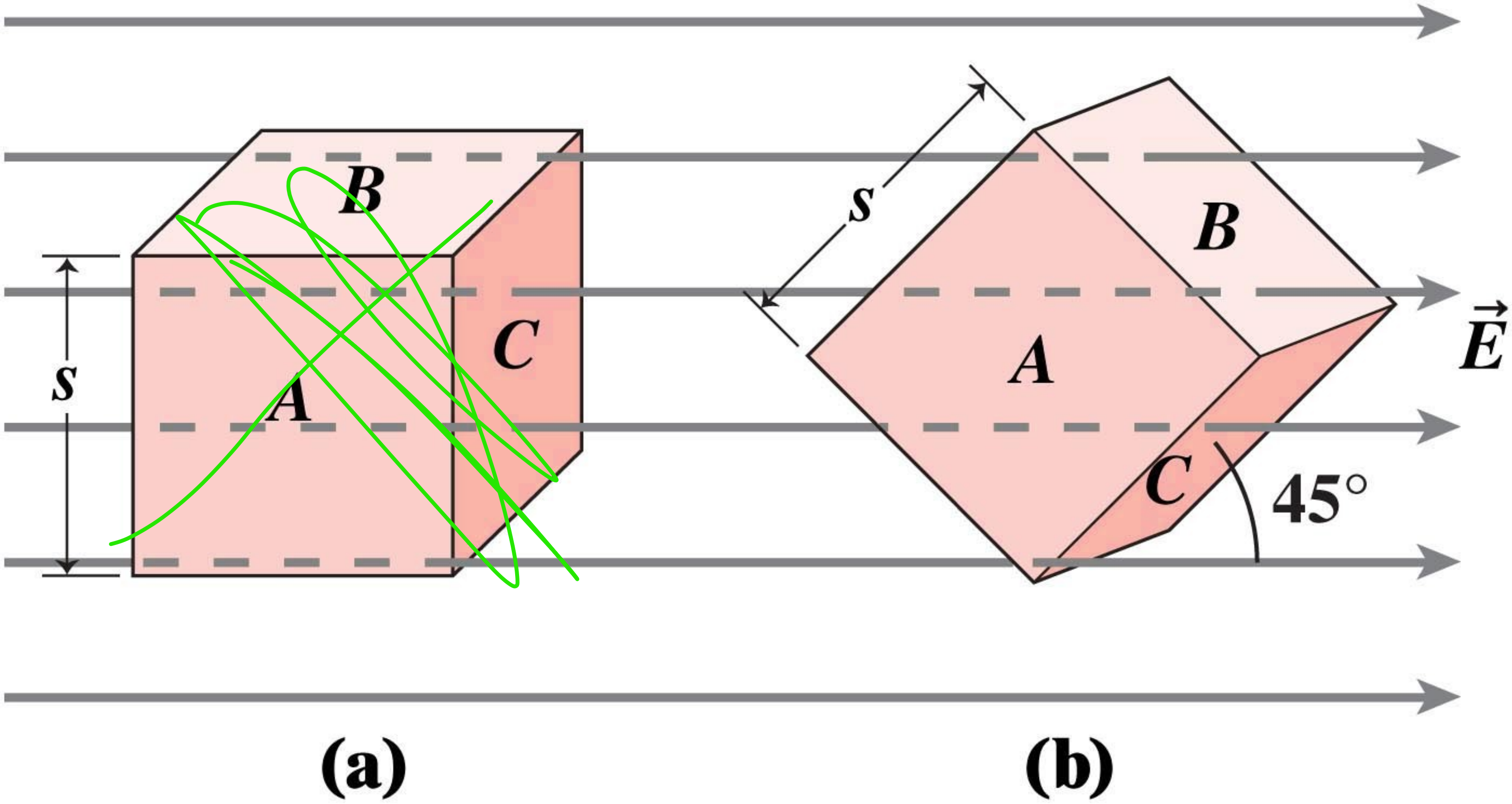
Flux – Cube "b"

Given E=10 N/C

s= 2 m

Flux through

C and A is?



(A) $10, \ 0 \ \mathrm{N\,m^2/C}$

(B) $4, \ 4 \ \mathrm{N\,m^2/C}$

(C) $0, \ 40 \ \mathrm{N\,m^2/C}$

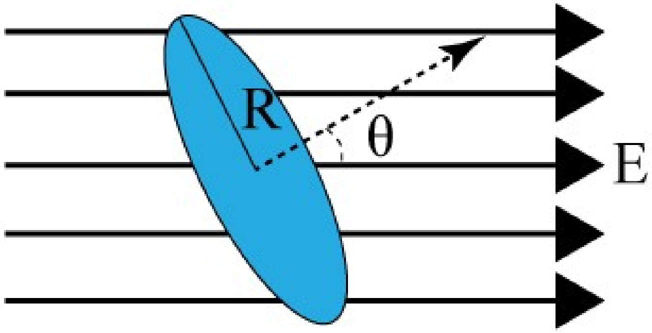
(D) $28.8, \ 0 \ \mathrm{N\,m^2/C}$

(E) $40, \ 0 \ \mathrm{N\,m^2/C}$

Online HW #3: Electric field and Gauss's Law Begin Date: 2/2/2024 8:00:00 AM -- **Due Date:** 2/6/2024 11:59:00 AM **End Date:** 5/29/2024 11:59:00 PM

(10%) Problem 8: A uniform electric field of magnitude 21.1 N/C is parallel to the x axis. A circular loop of radius 25.7 cm is centered at the origin with the normal to the loop pointing 30.9° above the x axis.

Sonnenfeld, Richard - Richard.Sonnenfeld@nmt.edu_StudentView



50% Part (a) Calculate the electric flux in, newton squared meters per coulomb, through the loop.

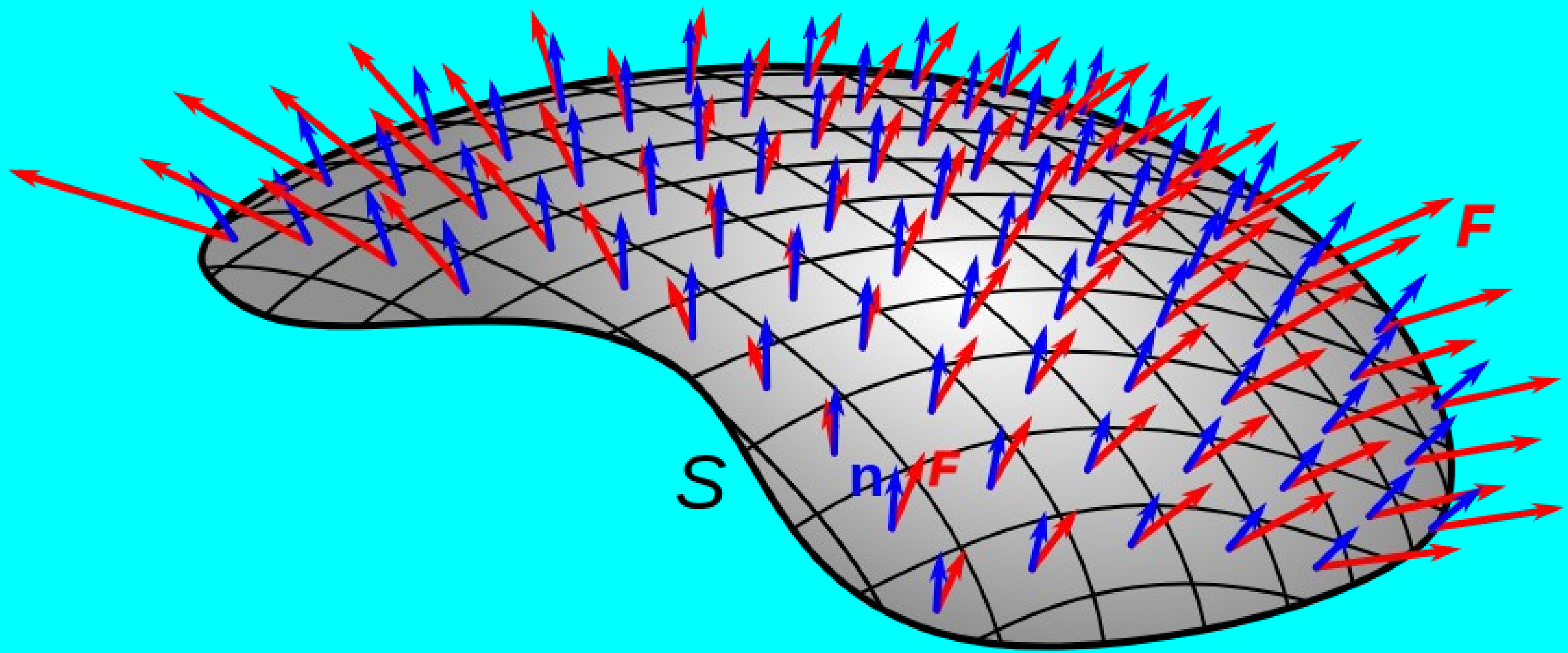
Φ = ______ $N \cdot m^2/C$

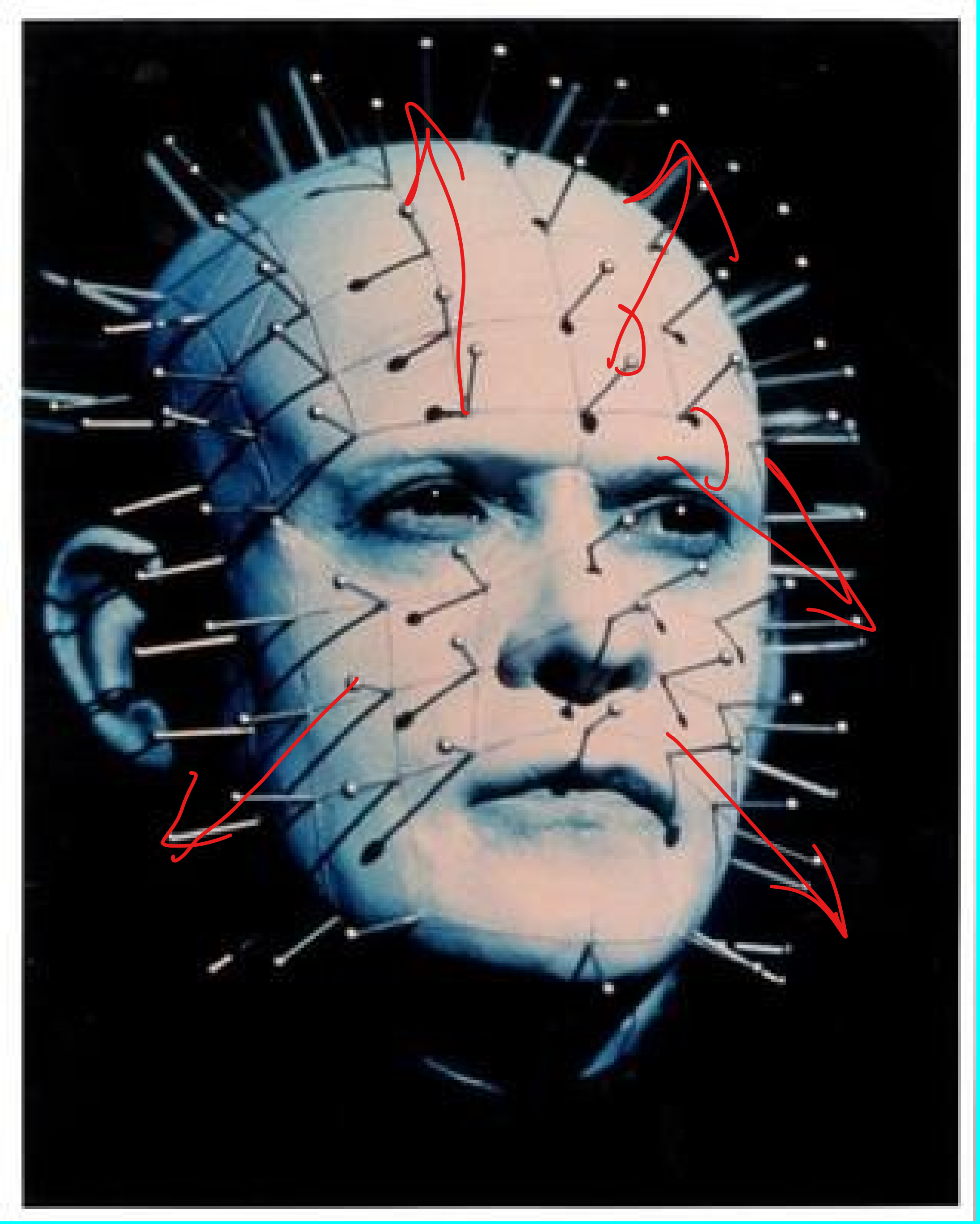
sin()	cos()	tan()	π	(	)	7	8	9	HOME
cotan()	asin()	acos()	E	↑^	^↓	4	5	6	←
atan()	acotan()	sinh()		/	*	1	2	3	→
cosh()	tanh()	cotanh()		+	-	0		.	END
Degrees	Radians			√()	BACKSPACE		DEL	CLEAR	

Submit | Hint | Feedback | I give up!

Grade Summary
Deductions 0%
Potential 100%

Submissions
Attempts remaining: 6
(1% per attempt)
detailed view


F
S
n
F

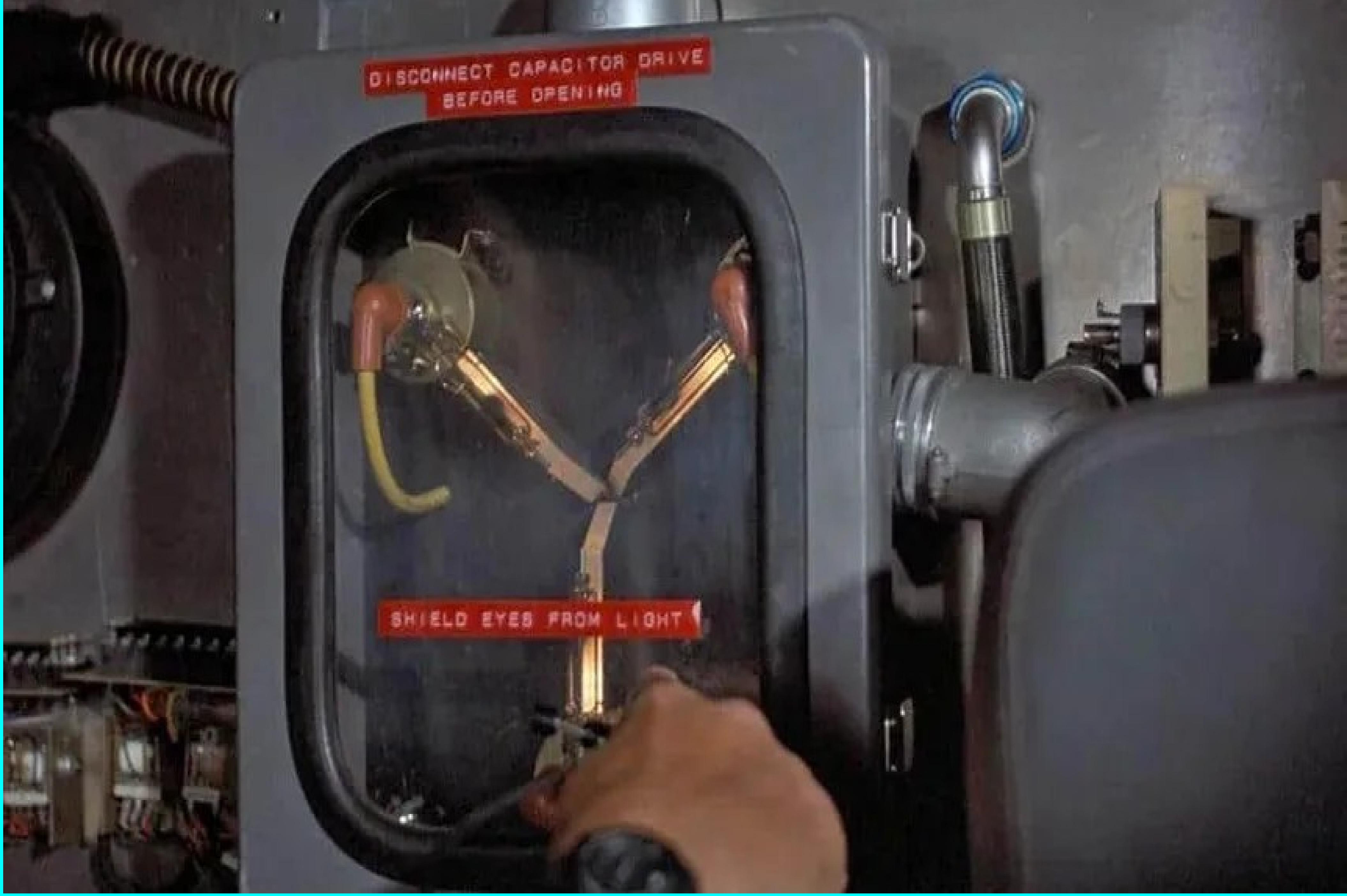


Gauss's law

"The total flux through any closed surface is equal to the enclosed charge over epsilon naught".

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\epsilon_0}$$

WTF?


DISCONNECT CAPACITOR DRIVE
BEFORE OPENING
SHIELD EYES FROM LIGHT

Epsilon_Naught

$$E = k\frac{q}{r^2} \qquad E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

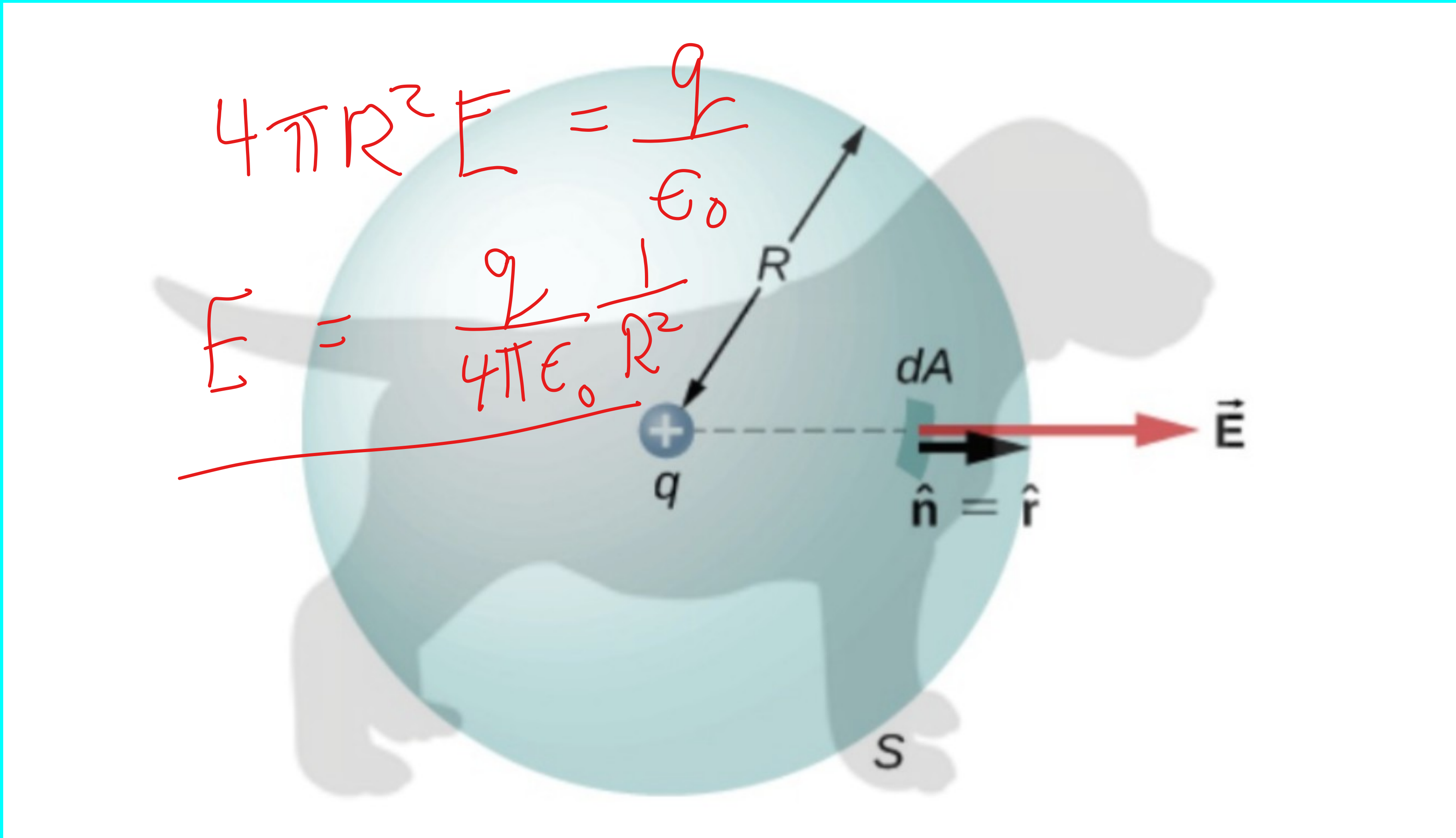
$\epsilon_0 = 8.85\times10^{-12}\ \frac{F}{m}$

$k = 9.00\times10^{9}$

$\frac{1}{4\pi\epsilon_0} = k = 9\times10^{9}$

$\epsilon_0 = \frac{1}{(4\pi)(9\times10^{9})}$

$8.85\times10^{-12} = \epsilon_0$



$$4\pi R^2 E = \frac{q}{\epsilon_0}$$

$$E = \frac{q}{4\pi\epsilon_0}\frac{1}{R^2}$$

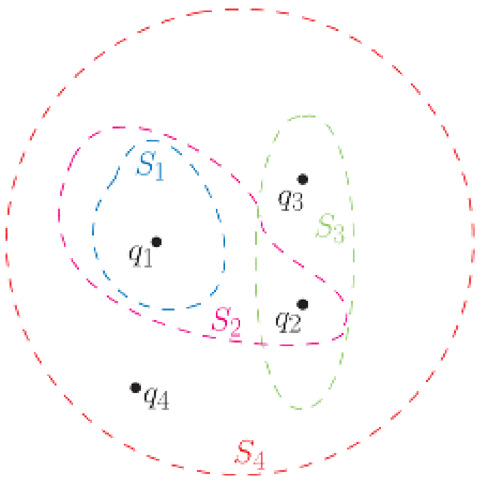
$$\Phi = \oint \vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0}$$

$$I = \int f(x)\,dx$$

Online HW #3: Electric field and Gauss's Law Begin Date: 2/2/2024 8:00:00 AM -- **Due Date:** 2/6/2024 11:59:00 AM **End Date:** 5/29/2024 11:59:00 PM

(10%) Problem 10: A collection of four charges and four Gaussian surfaces are shown in the figure. The charges have values:

$q_1 = +5.96$ nC
$q_2 = -5.96$ nC
$q_3 = +11.7$ nC
$q_4 = -13.3$ nC



The dashed lines represent the intersection of the closed three-dimensional surfaces with the plane of the image. If a charge is shown within a dashed curve, then it is contained with the corresponding surface.

25% Part (a) What is the electric flux, in newton squared meters per coulomb, through the first closed surface, S_1?

Φ_1 = [ ] $N \cdot m^2/C$

sin()	cos()	tan()	π	(	)	7	8	9	HOME
cotan()	asin()	acos()	E	↑^	^↓	4	5	6	←
atan()	acotan()	sinh()		/	*	1	2	3	→
cosh()	tanh()	cotanh()		+	-	0		.	END
Degrees	Radians			√()	BACKSPACE		DEL	CLEAR	

Submit | Hint | Feedback | I give up!

Grade Summary
Deductions 0%
Potential 100%

Submissions
Attempts remaining: 6
(1% per attempt)
detailed view

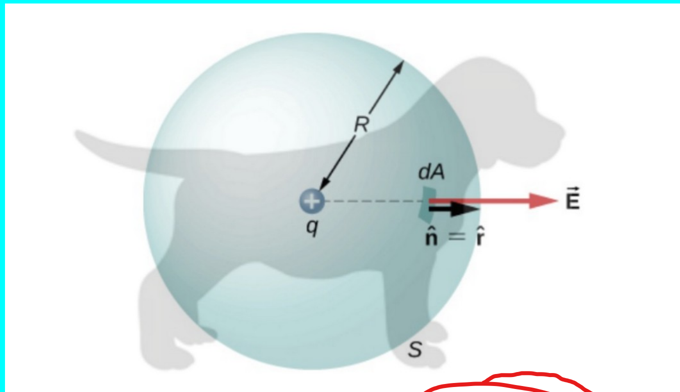
Hints: 0% deduction per hint. Hints remaining: 2

Feedback: 0% deduction per feedback.

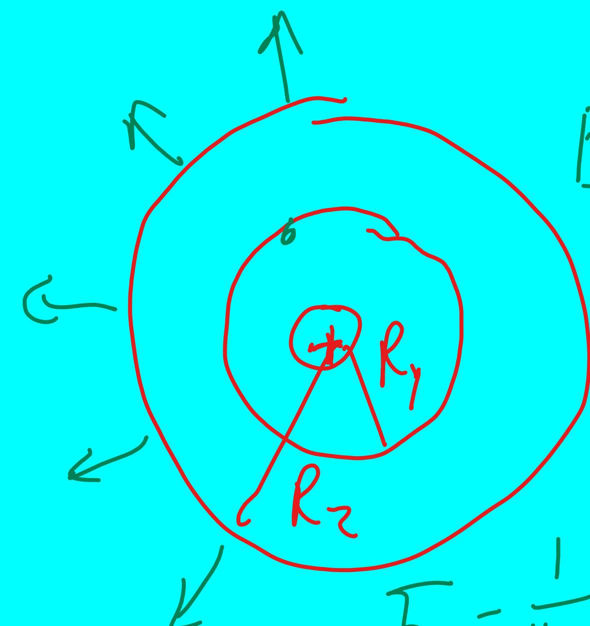
25% Part (b) What is the electric flux, in newton squared meters per coulomb, through the second closed surface, S_2?

25% Part (c) What is the electric flux, in newton squared meters per coulomb, through the third closed surface, S_3?

25% Part (d) What is the electric flux, in newton squared meters per coulomb, through the fourth closed surface, S_4?



$$F = \frac{1}{4\pi\epsilon}\frac{q^2}{r^2}$$



$$E_1 4\pi R_1^2 = \Phi_1$$

$$E_2 4\pi R_2^2 = \Phi_2$$

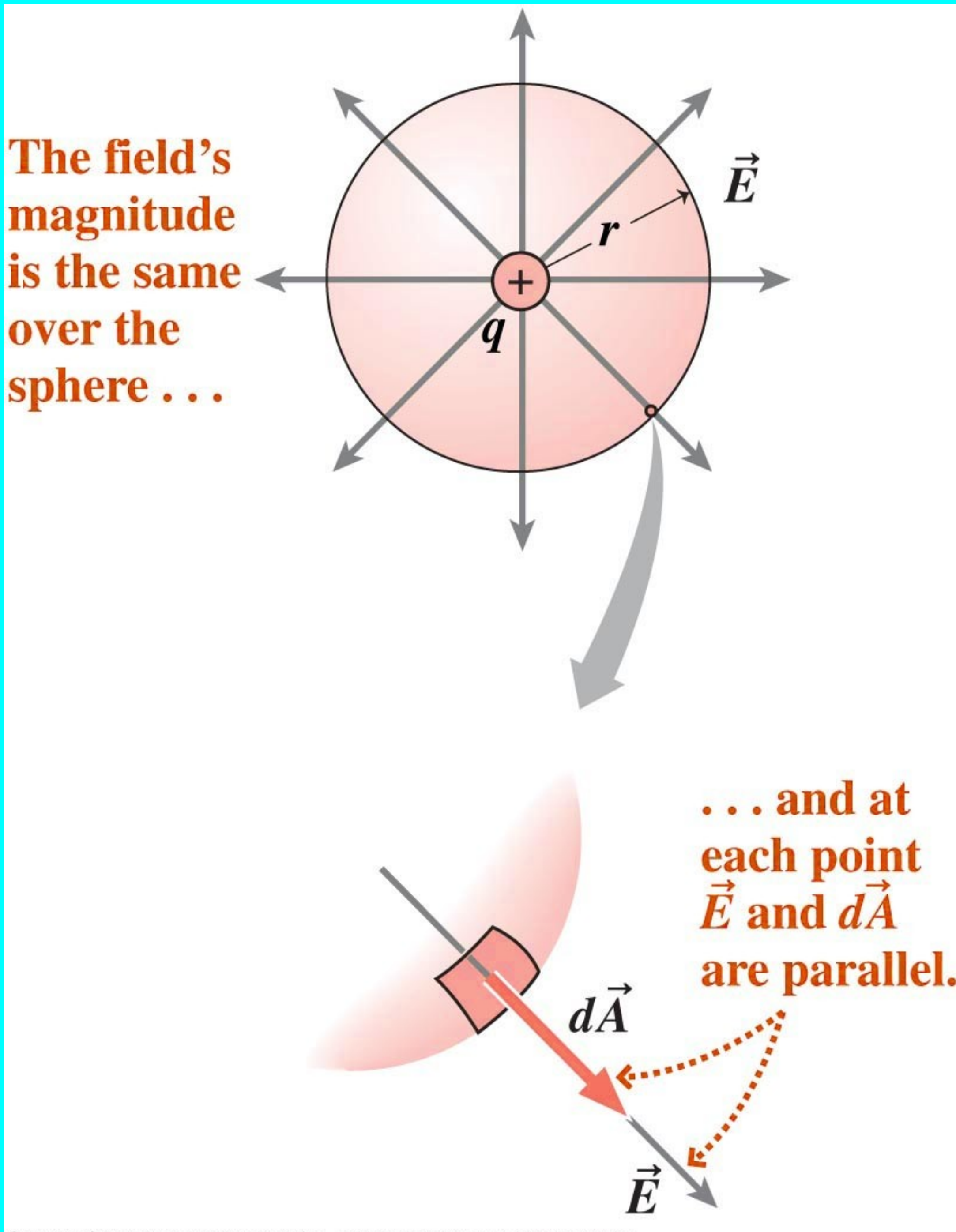
$$\Phi = \int \vec{E}\cdot d\vec{A}$$

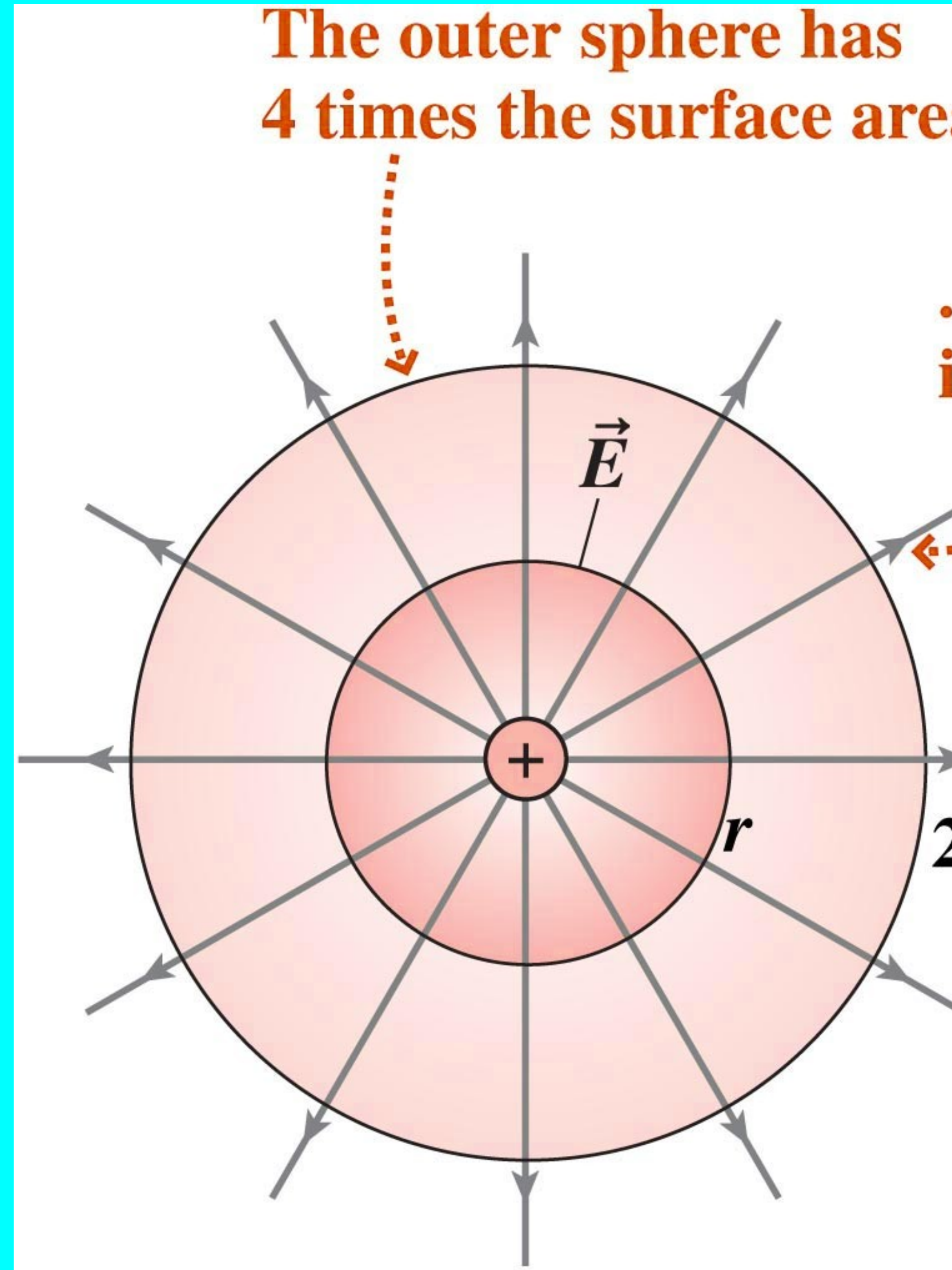
E · Surface Area

$$\Phi_1 = \frac{1}{4\pi\epsilon_0}\frac{q}{R_1^2} 4\pi R_1^2$$

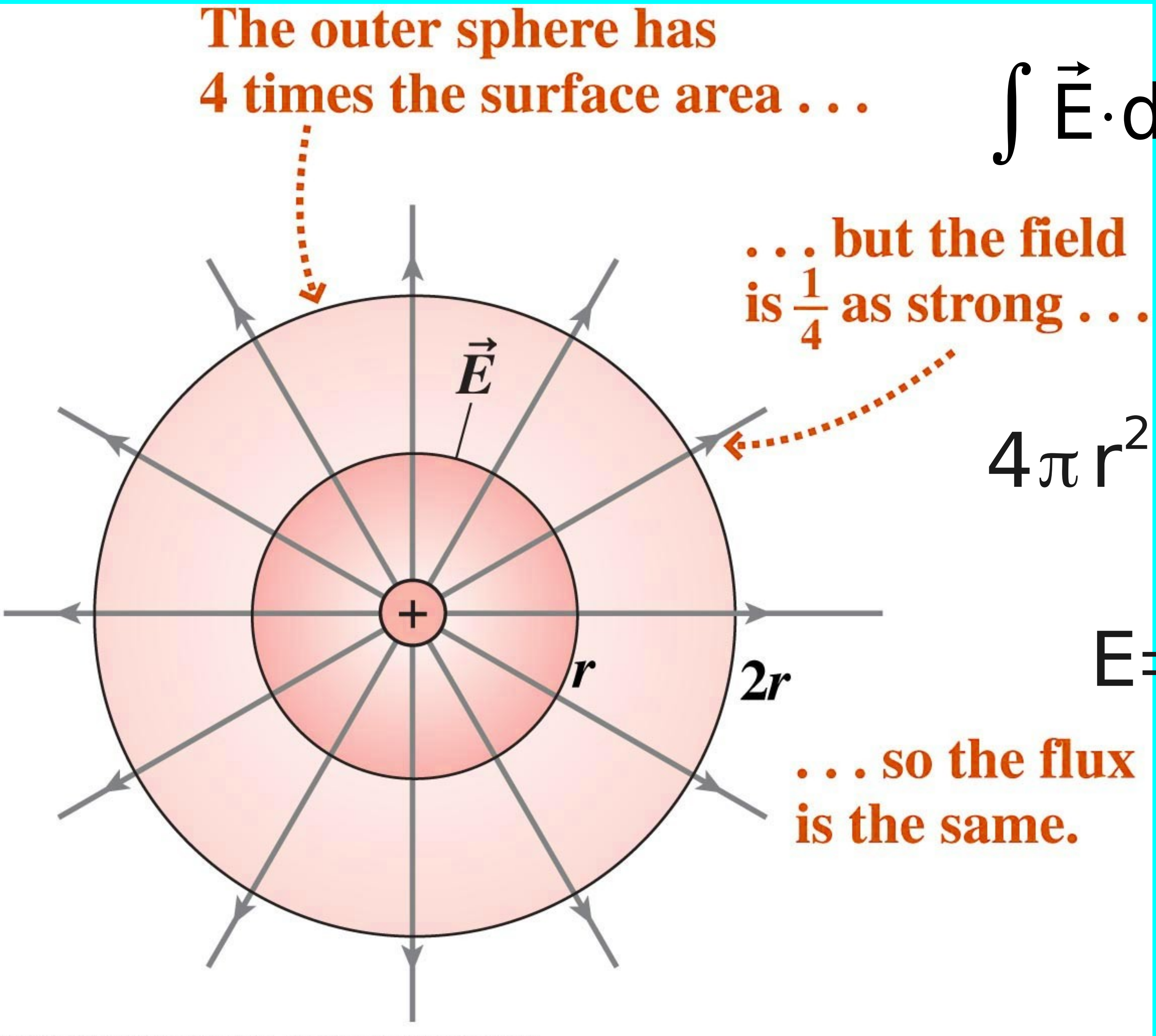
$$\Phi_2 = \frac{1}{4\pi\epsilon_0}\frac{q}{R_2^2} 4\pi R_2^2$$

Gauss's law is a generalization of Coulomb's law





Gauss's law is a generalization of Coulomb's law



$$\int \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\epsilon_0}$$

$$4\pi r^2 E = \frac{q_{enclosed}}{\epsilon_0}$$

$$E = \frac{q_{enclosed}}{4\pi\epsilon_0} \frac{1}{r^2}$$

$$E = \frac{kq}{r^2}$$

Next Class:

How to use Gauss' law to calculate electric fields