Your questions/comments

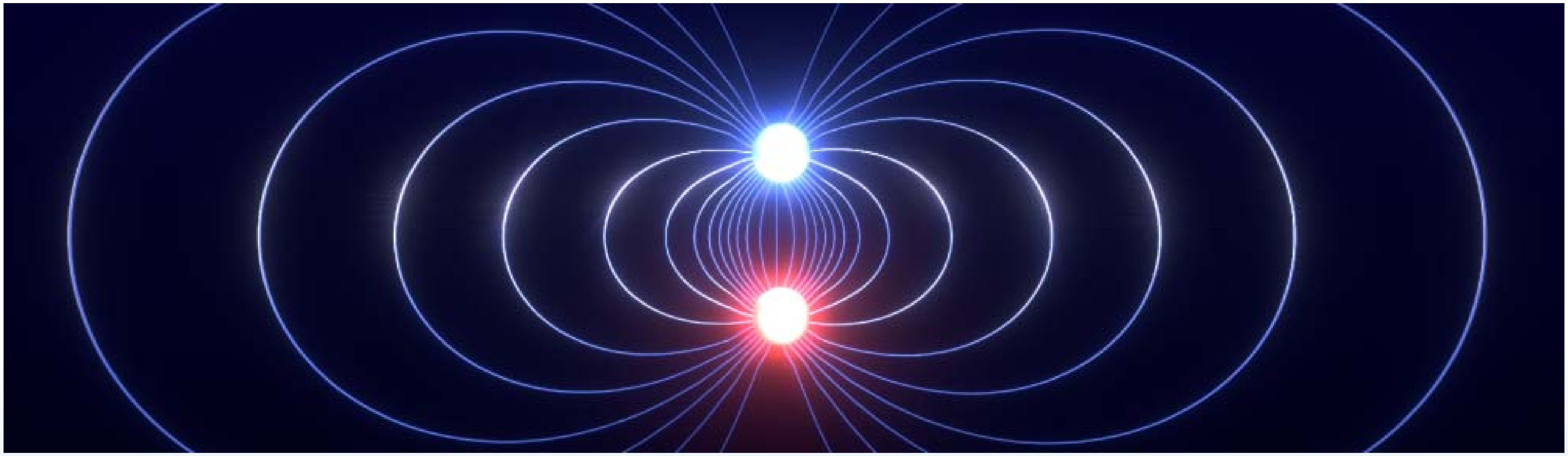
“I'm still not sure how to identify which way the vector will go based on the charges.”

“I'm having a difficult time understanding the concept of field lines and how to determine the direction to draw them.”

“Determining how to distinguish which point would have a higher magnitude when it comes to electric fields.”

“I did not fully understand the concept of the Superposition of Electric Fields- The Electric Dipole.”

“I would like to have a couple examples of mapping out an electric field based on different positions/combinations of negative and positive charges.”



Phys 102 – Lecture 3

The Electric field

Today we will...

- Learn about the *electric field*
- Apply the superposition principle

  Ex: Dipole, line of charges, plane of charges
- Represent the E field using electric field lines
- Apply these concepts!

  Dipoles in electric fields

  Conductors in electric fields

The electric field

The electric field is defined at a *location* in space around a charge or set of charges

Field at position *P* → $$\vec{E} \equiv \frac{\vec{F}}{q}$$

Force a charge *q* at position *P* *would* feel

Charge *q*

Magnitude

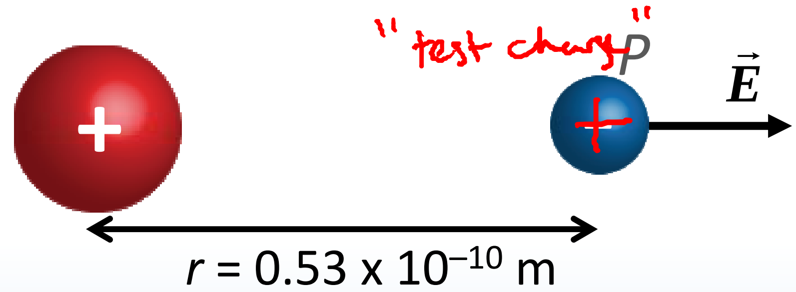
Magnitude given by: $E = \frac{F}{|q|}$ Units: N/C

Direction

Direction is the same as for the force that a + charge *would feel* at that location

Calculation: Electric field in H atom

What is the magnitude of the electric field due to the proton at the *position* of the electron?



$$E = \frac{F}{|q_e|} = \frac{k|q_p|}{r^2} = \frac{9\times10^9\,\mathrm{N\cdot m^2/C^2}\,|1.6\times10^{-19}\,\mathrm{C}|}{(0.53\times10^{-10}\,\mathrm{m})^2} = 5.1\times10^{11}\,\frac{\mathrm{N}}{\mathrm{C}}$$

This is a large electric field!
Inside electrical wire: 10^{-2} N/C
Needed to create a spark in air: 10^{6} N/C

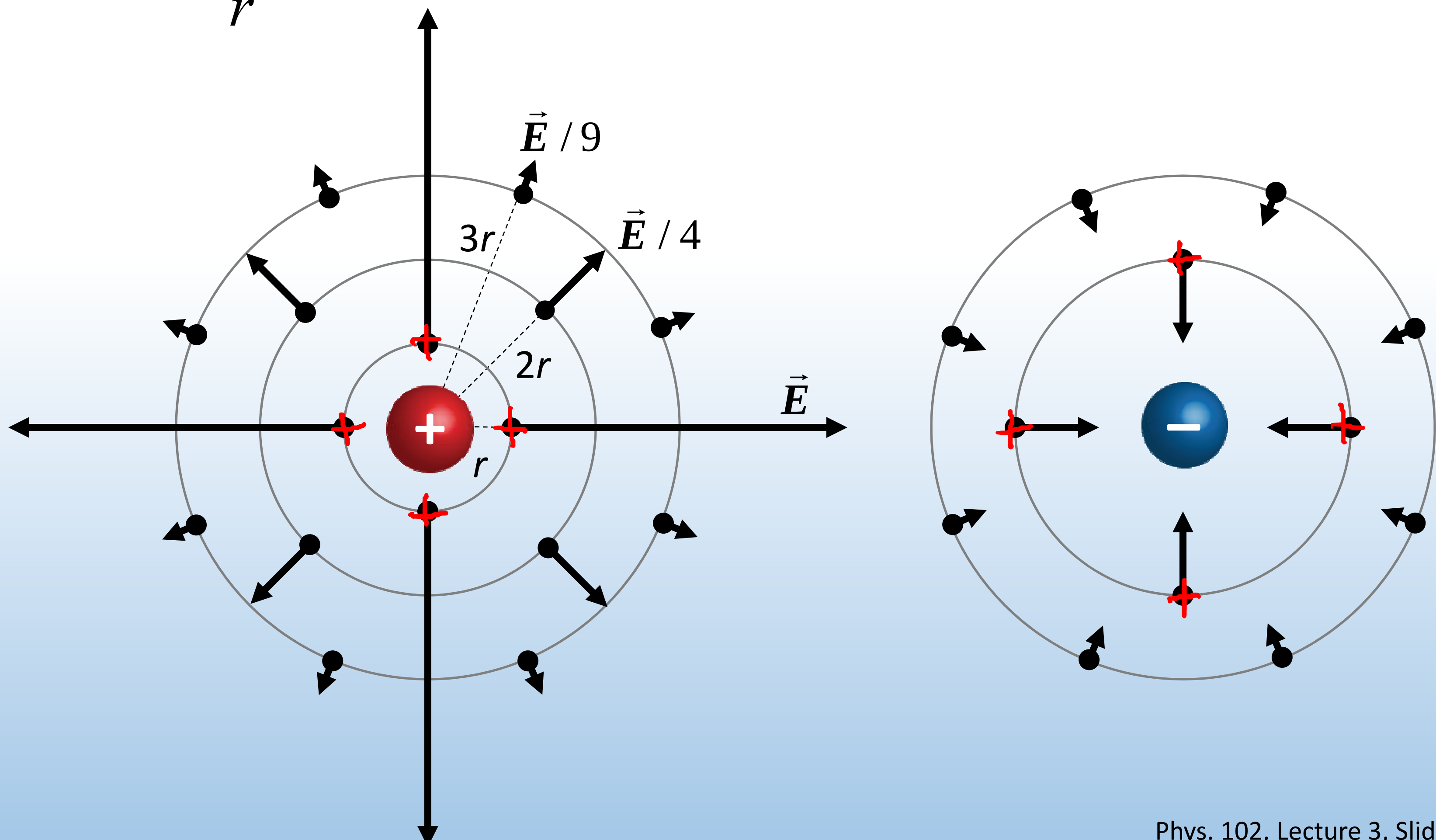
What is the direction?

Direction is the same as for the force that a + charge *would feel* at that location

Electric field from + and – charges

Magnitude $E = \frac{k|q|}{r^2}$

Direction Away from + charge, toward – charge

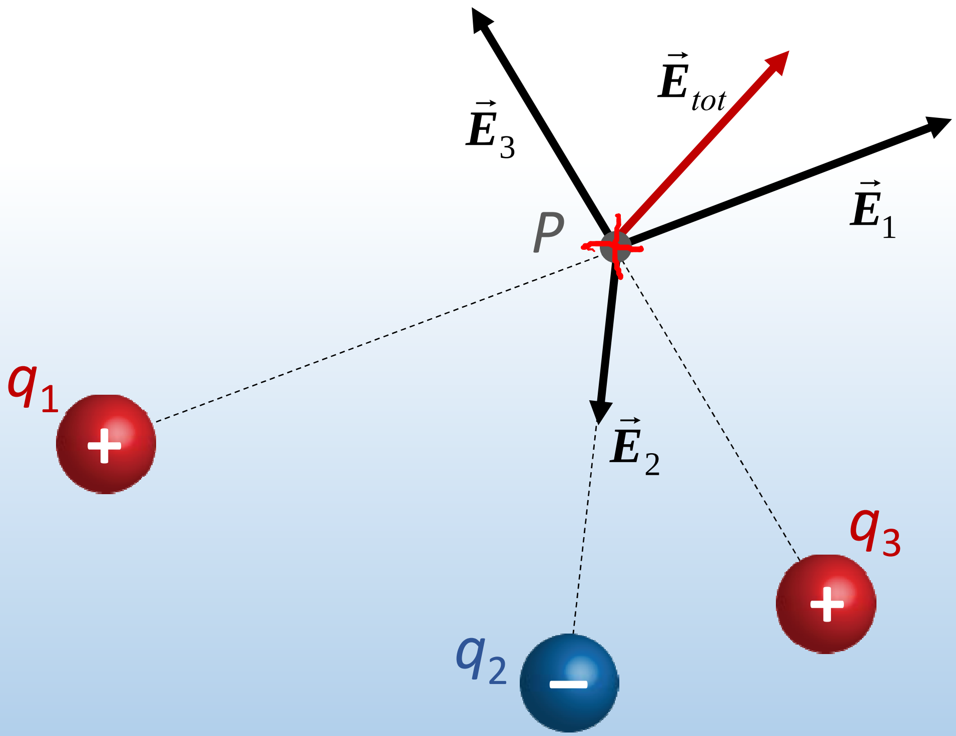


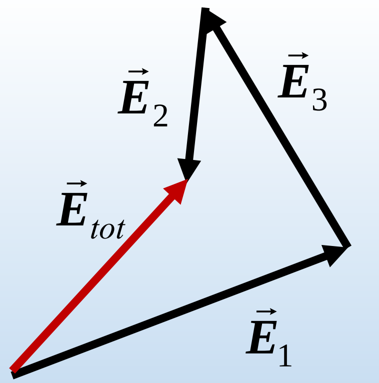
Superposition principle

Total E-field due to several charges = sum of individual E-fields

$$\vec{E}_{tot} = \sum \vec{E}$$

Ex: what is the E-field at point P due to q_1, q_2, and q_3?





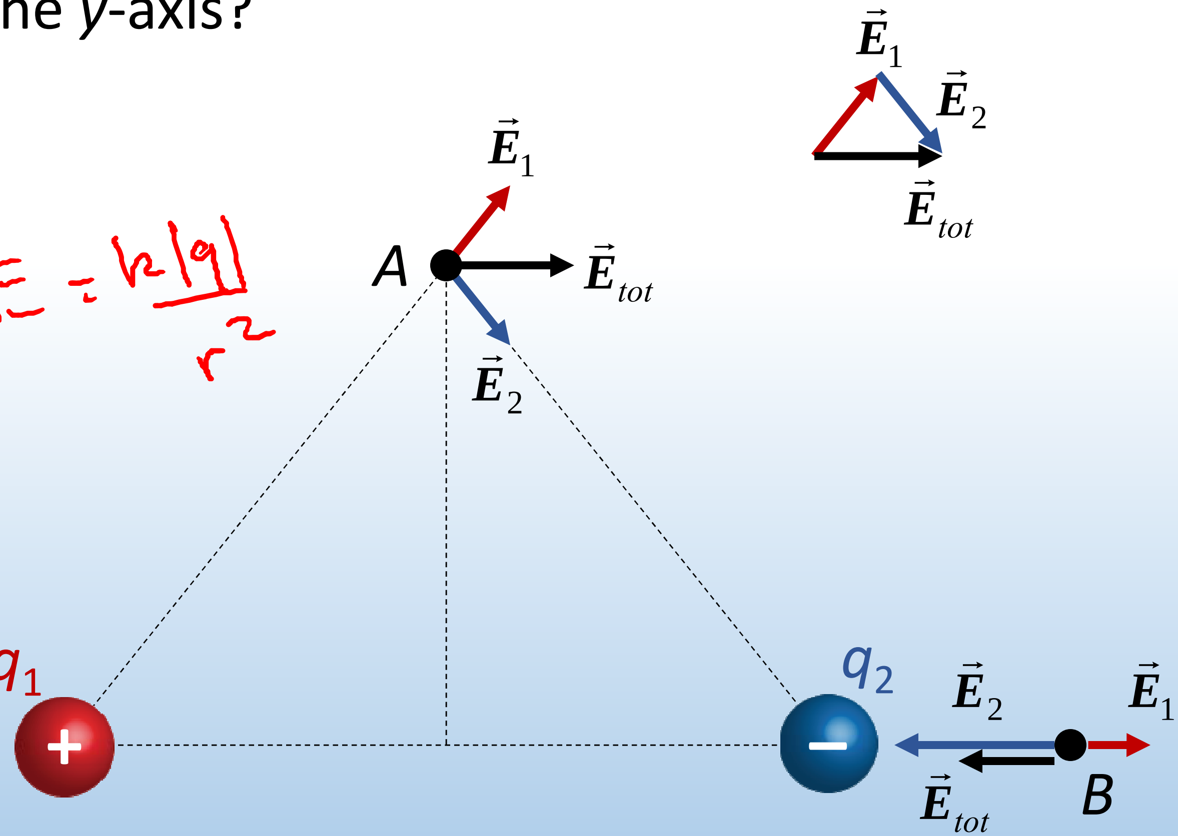
Order does not matter!

Same approach
as for force

$$\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

ACT: CheckPoint 1.1

Two equal, but opposite charges are placed on the x-axis at $x = -5$ and $x = +5$. What is the direction of the electric field at point A on the y-axis?



A. Up 9%

B. Down 12%

C. Left 4%

D. Right 46%

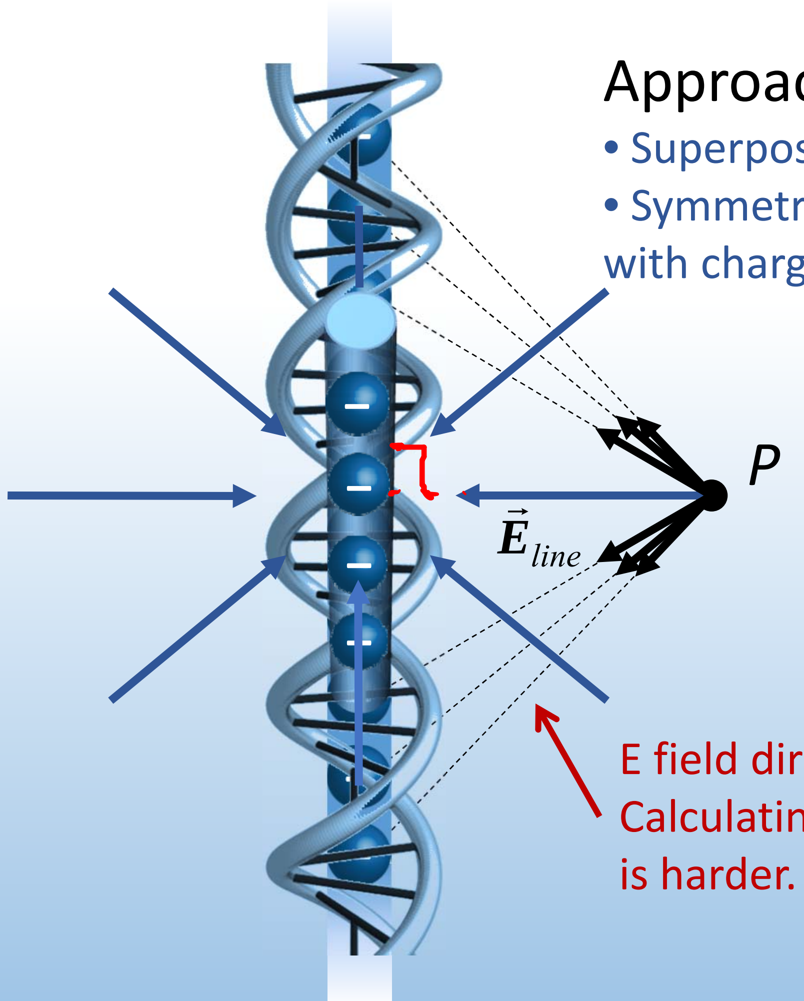
E. Zero 28%

Other locations?

Checkpoint 1.2

ACT: Line of charge

Consider a very long line of identical negative charges (ex: DNA). What is the direction of electric field at point *P*?



Approach:

- Superposition principle
- Symmetry: charge above *P* pairs up with charge below *P*

E field direction is radial. Calculating a magnitude is harder. Need calculus!

A. Up

B. Down

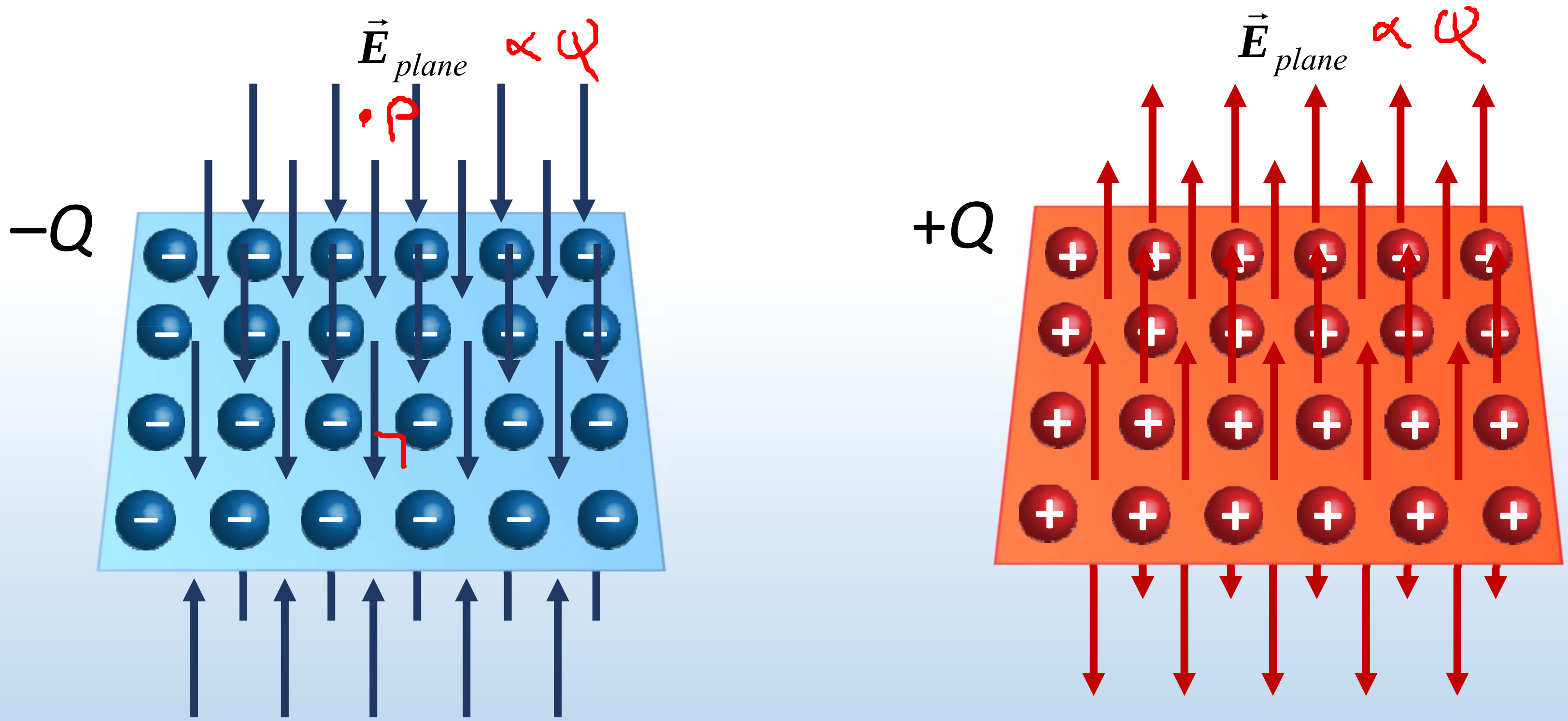
C. Left

D. Right

E. Zero

Plane of charge

A large plane of charges creates a *uniform* electric field (constant magnitude, direction)

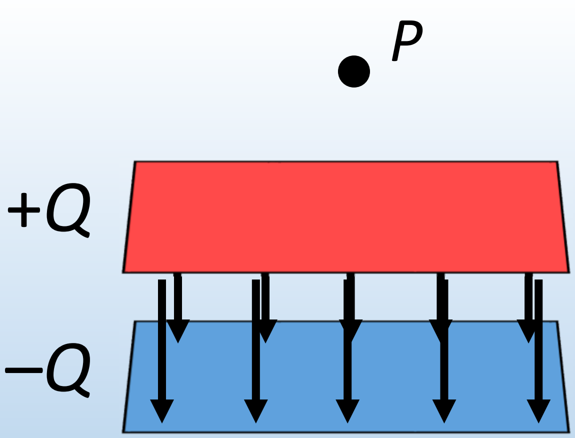


Approach: Superposition principle & symmetry

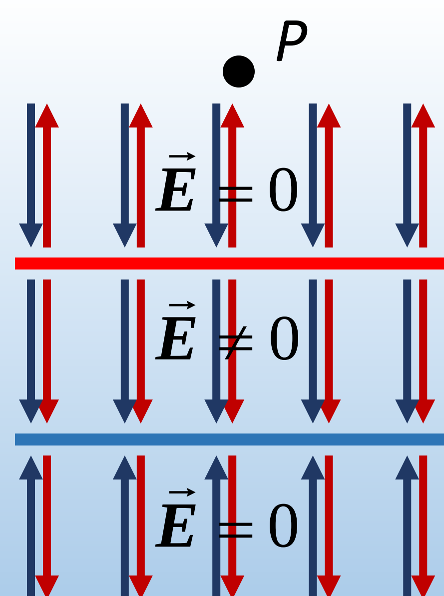
ACT: two charged planes

Consider two large parallel planes with equal and opposite charge +*Q* and –*Q* separated by a small distance

If the electric field from one plane is E_{plane}, what is the magnitude of total electric field at position *P* above the two parallel planes?



E field is uniform between plates, 0 everywhere else!



A. 0

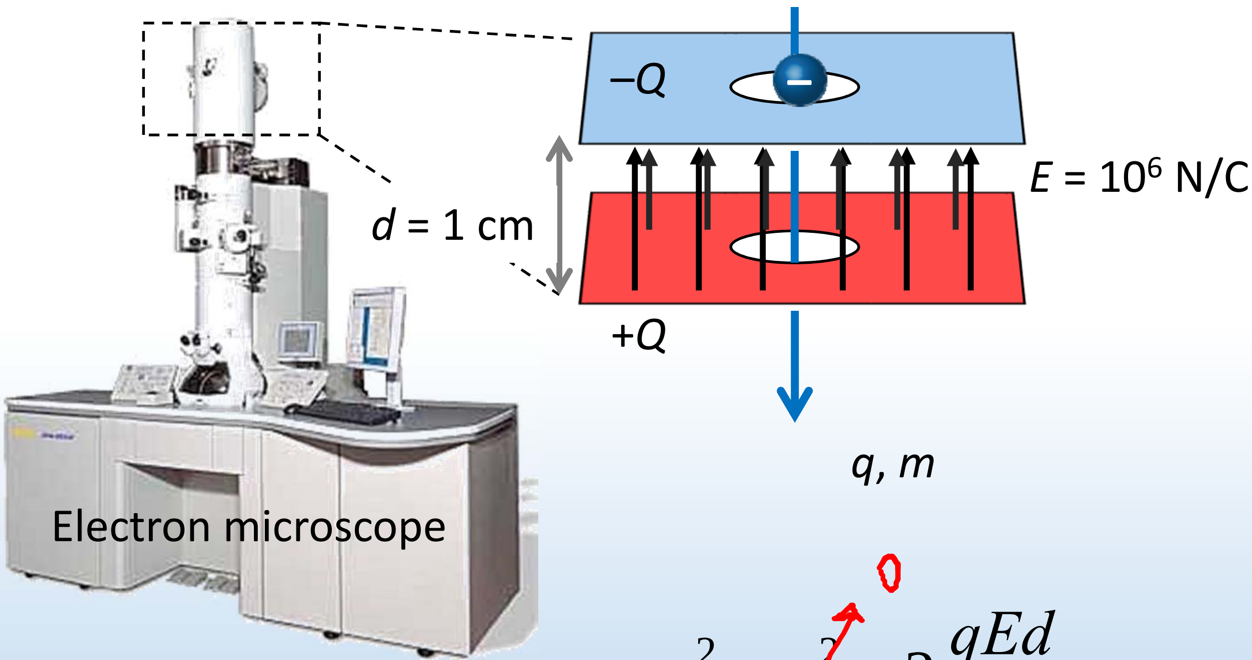
B. $E_{plane}/2$

C. $2E_{plane}$

DEMO

Calculation: Electron microscope

A uniform E field generated by parallel plates accelerates electrons in an electron microscope. If an electron starts from rest at the top plate what is its final velocity?



$$F_e = qE = ma$$

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a\Delta x$$

Kinematics! (Phys. 101)

$$v^2 = v_0^2 + 2\frac{qEd}{m}$$

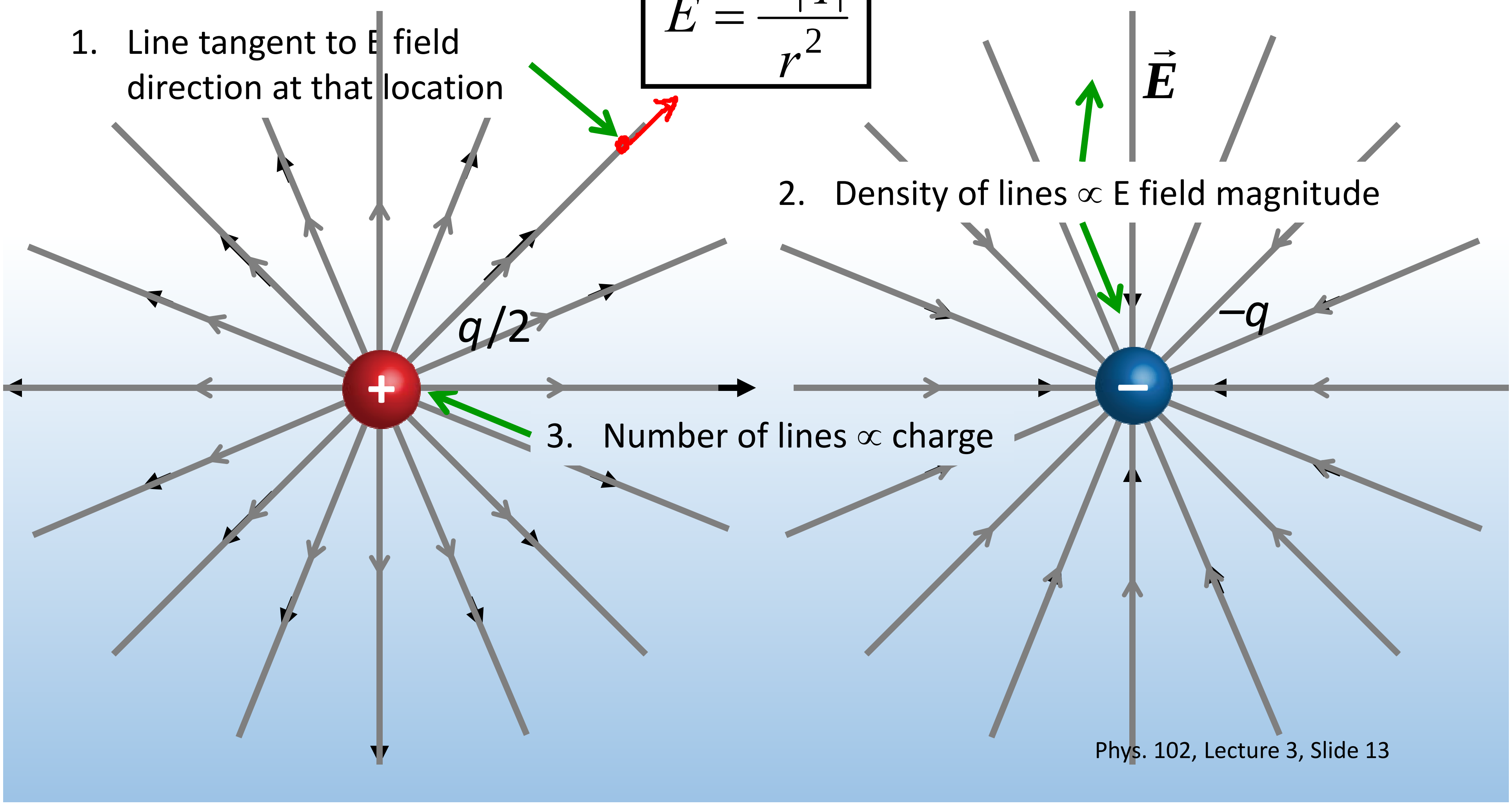
$$v = \sqrt{2\frac{1.6\times10^{-19}\cdot10^{6}\cdot0.01}{9.11\times10^{-31}}} = 5.9\times10^{7}\ \mathrm{m/s}$$

We'll learn an easier way to solve this in Lect. 4

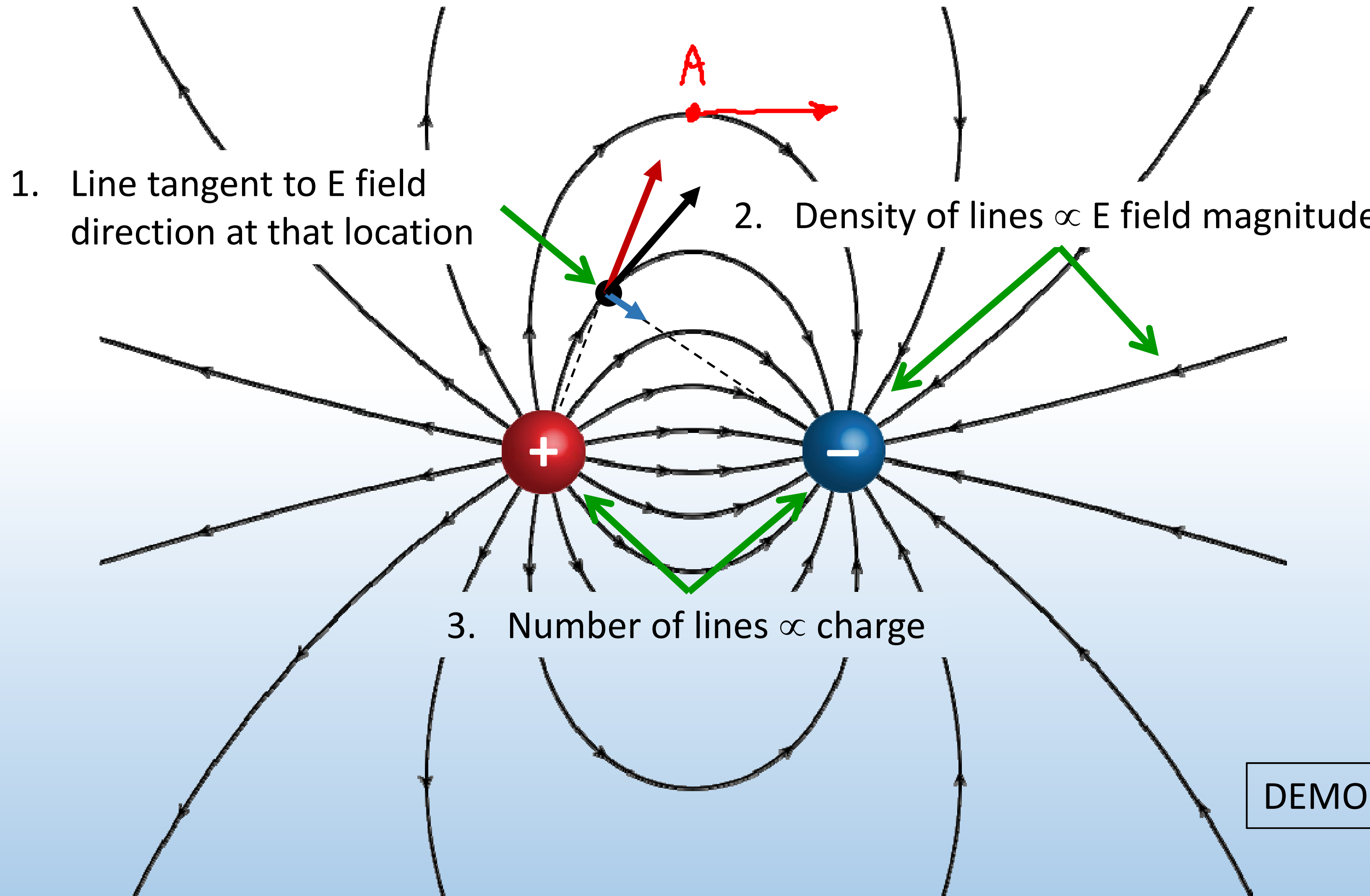
Electric field lines for charges

Electric field lines represent E field direction and magnitude graphically

$$E = \frac{k|q|}{r^2}$$

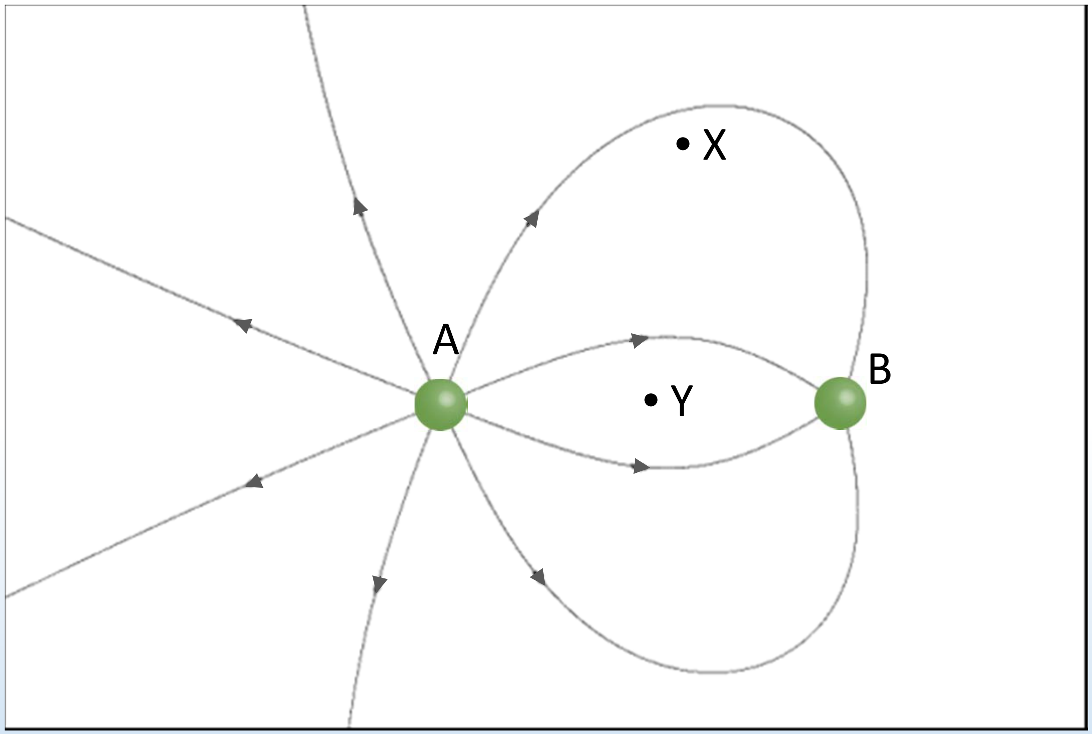


Electric field lines for dipoles



DEMO

CheckPoint 2.1

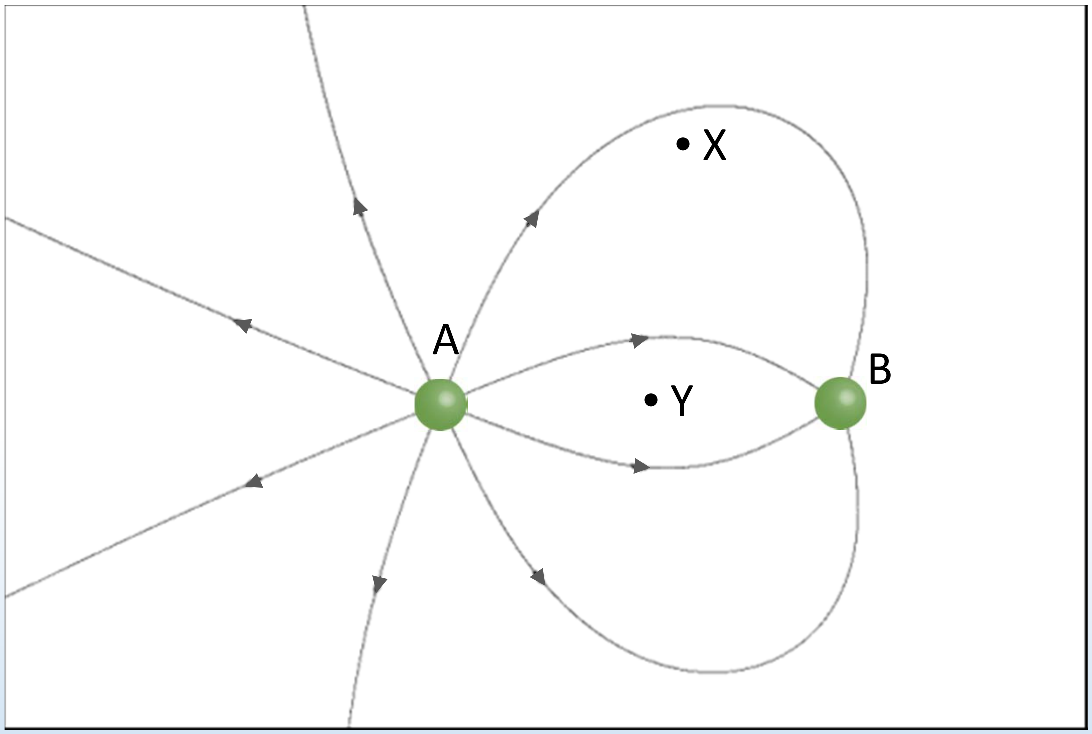


Charge A is Field lines start on positive charge, end on negative.

A. positive B. negative C. unknown

83% 10% 7%

ACT: CheckPoint 2.2



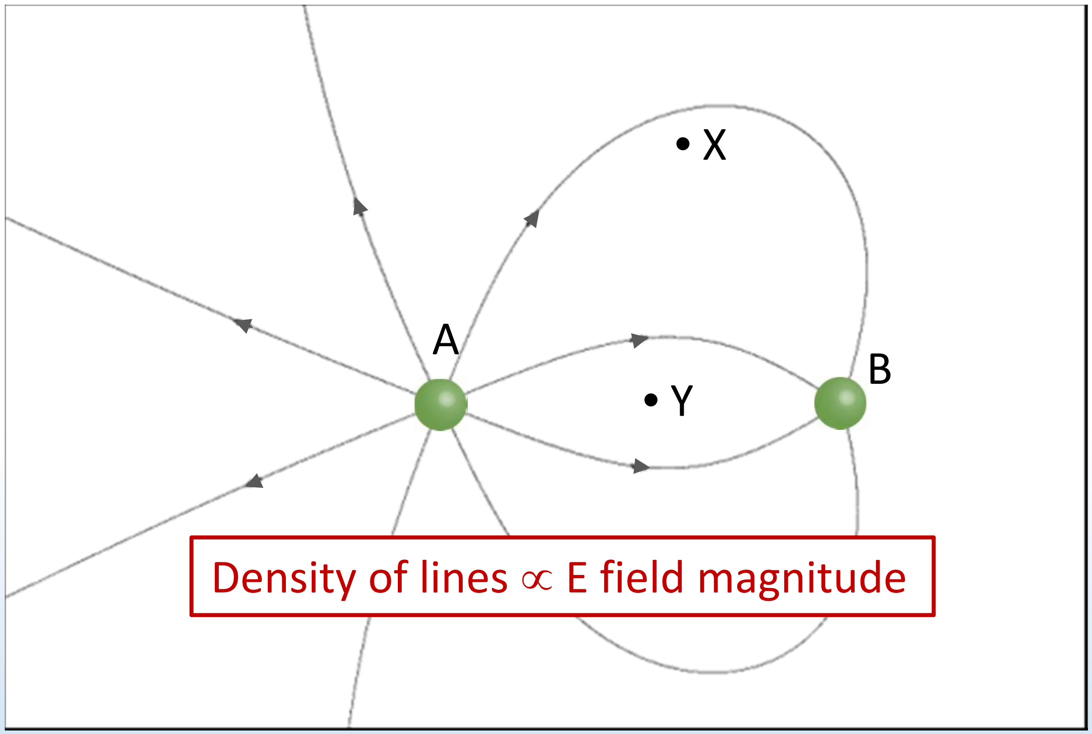
Compare the charges $|Q_A|$ & $|Q_B|$ # lines proportional to Q

A. $|Q_A| = |Q_B|/2$ 20%

B. $|Q_A| = |Q_B|$ 21%

C. $|Q_A| = 2|Q_B|$ 48%

ACT: CheckPoint 2.4



The magnitude of the electric field at point X is greater than at point Y

A. True

B. False

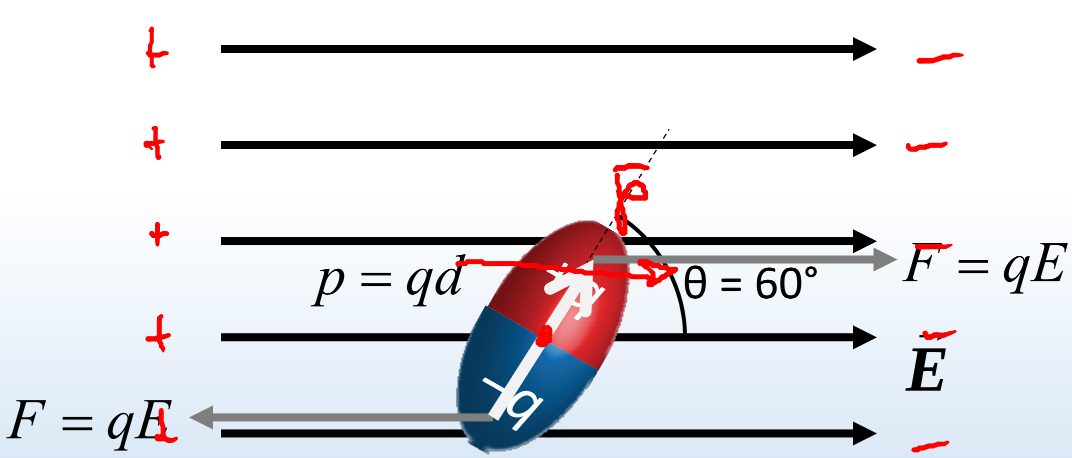
20%

80%

HW2

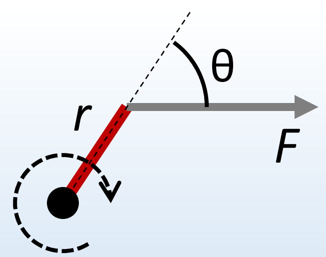
Calculation: dipole in E-field

An electric dipole with moment $p = 6.2 \times 10^{-30}$ C·m is placed in a uniform external electric field $E = 10^6$ N/C at an angle θ = 60°. Calculate the total *force* and *torque* on the dipole.



Force: $F_{tot} = 0$

Torque: $\tau = Fr\sin\theta$



Torque! (Phys. 101)

$$\tau_{tot} = 2qE\frac{d}{2}\sin\theta = pE\sin\theta$$

$$= 6.2\times10^{-30}\cdot10^{6}\sin(60^\circ)$$

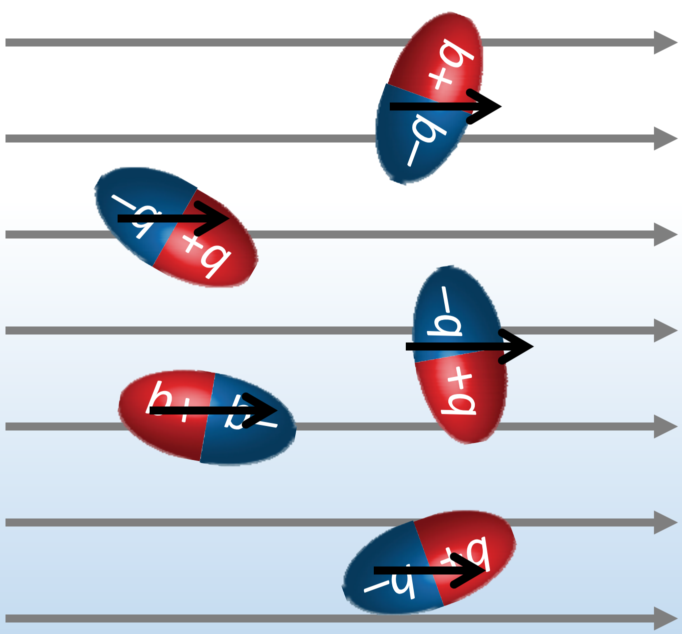
$$= 5.4\times10^{-24}\,\mathrm{Nm}$$

Dipole rotates until $\tau = 0$, *i.e.* when θ = 0°
Dipole moment aligns to E field

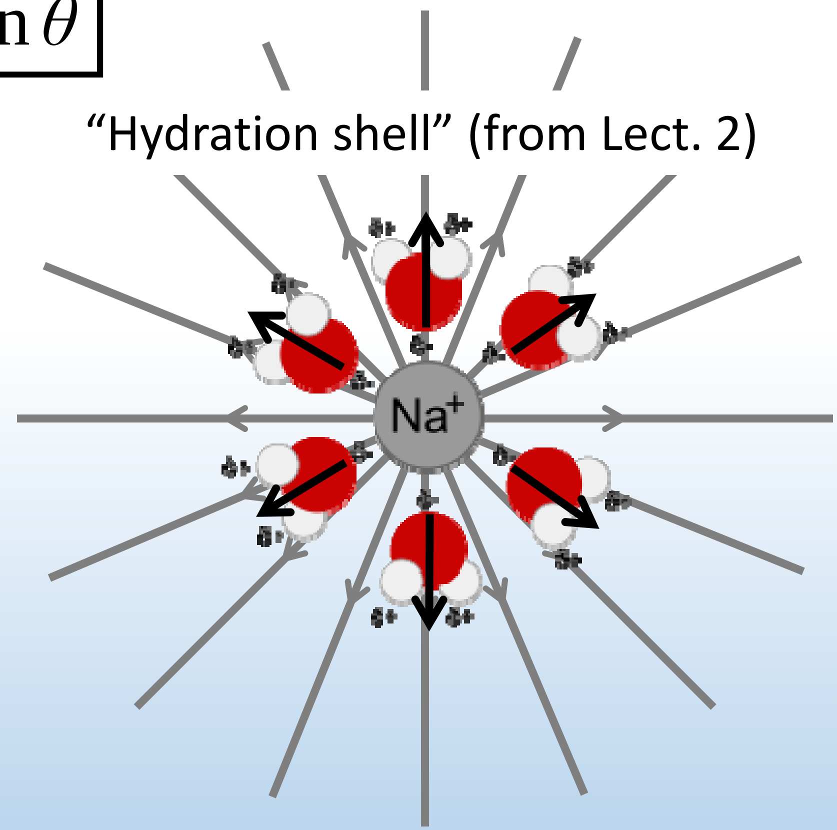
Dipole in E field

Electric dipole moments align parallel to electric field

$$\tau = pE \sin\theta$$



Dipoles in a uniform E field



Dipoles near a charge

DEMO

Conductors & electric fields

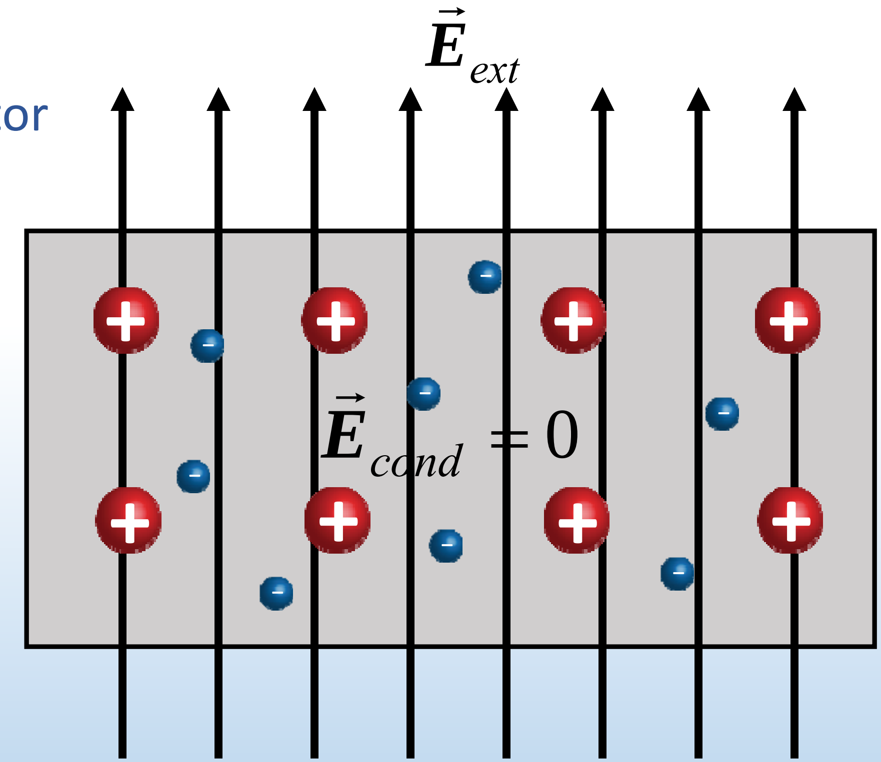
Imagine placing a conductor inside a uniform external E field

Charges are free to move in a conductor

Electrons move due to electric force until they feel no more force (***F*** = 0)

$$\vec{E}_{cond} = \frac{\vec{F}}{q} = 0$$

True everywhere inside conductor



Conductors & electric fields

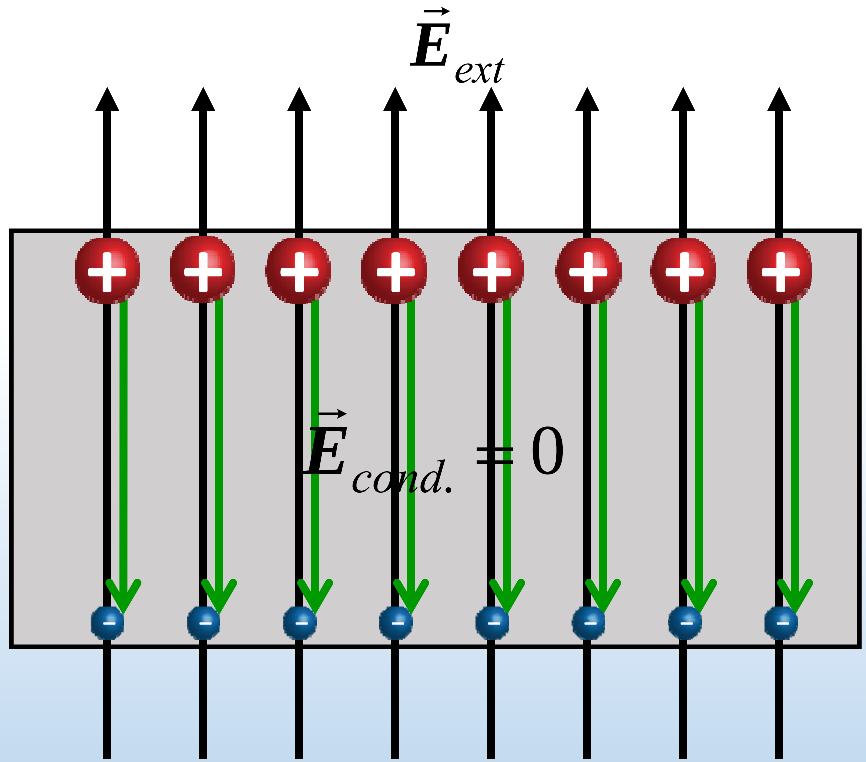
Imagine placing a conductor inside a uniform external E field

Another way to look at it:

–*Q* moves to the bottom surface
leaving excess +*Q* on top surface

Parallel planes of +*Q* and –*Q*
create own E field, cancel out
external E field

$$\vec{E}_{cond} = \vec{E}_{ext} + \vec{E}_{charges} = 0$$



True for *electrostatic equilibrium*
We'll see exception to this later in semester

Summary of today's lecture

- Electric fields
  - Electric field lines
- Superposition principle $\vec{E}_{tot} = \sum \vec{E}$
  - Dipole, line, plane
- Dipoles & electric fields
- Conductors & electric fields $\vec{E}_{cond.} = 0$