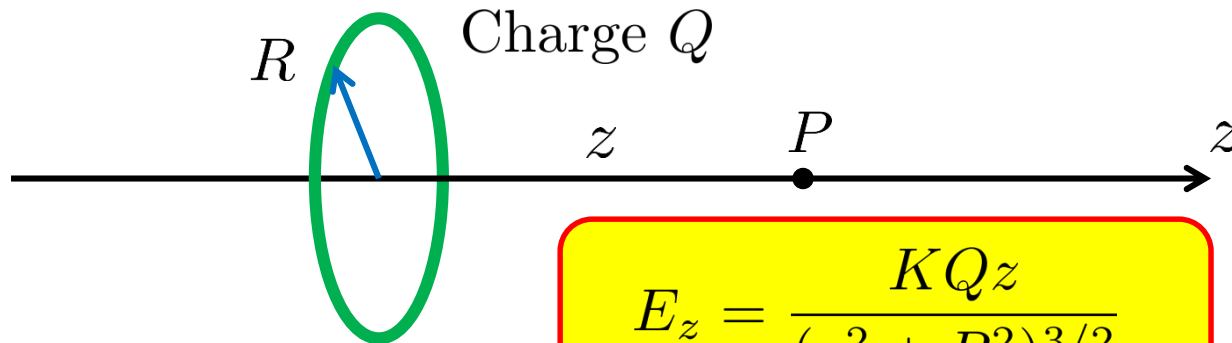


(23-2 continued) Some More Important Field Results

(from your text; we will occasionally use these results)

On the Axis of a Ring of Charge:

(Note: only valid on the axis)

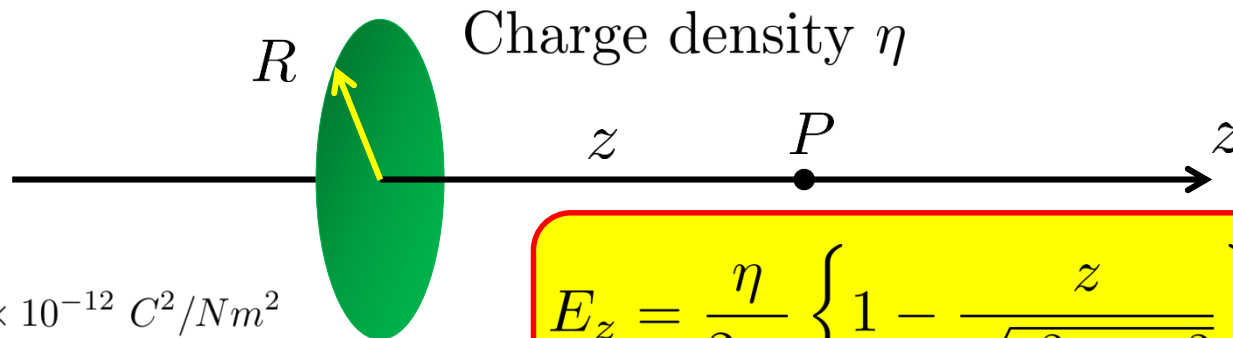


$$E_z = \frac{KQz}{(z^2 + R^2)^{3/2}}$$

(other components are zero by symmetry)

On the Axis of a Disk of Charge:

(Note: only valid on the axis)



$$E_z = \frac{\eta}{2\epsilon_0} \left\{ 1 - \frac{z}{\sqrt{z^2 + R^2}} \right\}$$

(other components are zero by symmetry)

$$\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$$

“Permittivity Constant”

A Really Important Field Result

Infinite Plane of Uniform Charge Density:

$$\vec{E} = \left\{ \begin{array}{l} \frac{|\eta|}{2\epsilon_0}, \text{ away for } \eta > 0 \\ \frac{|\eta|}{2\epsilon_0}, \text{ toward for } \eta < 0 \end{array} \right\}$$

η = charge/area

$$\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$$

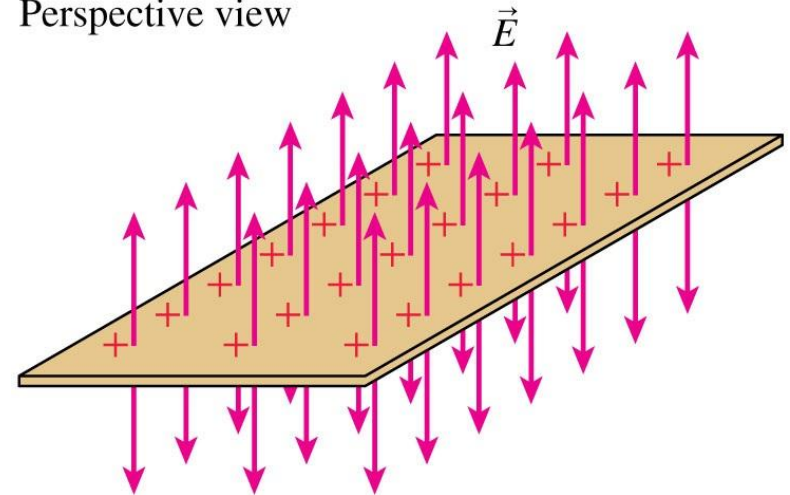
“Permittivity Constant”

Note: this is a uniform field with no distance dependence.

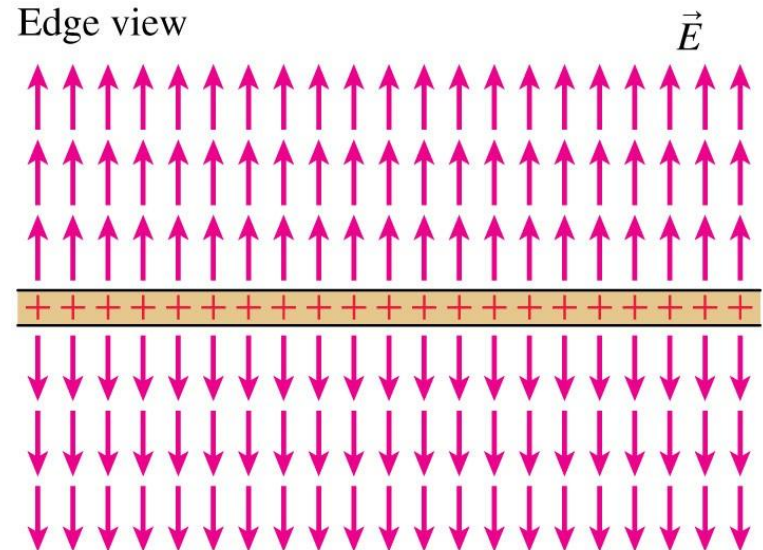
Where would we get an infinite plane of charge?

For a finite sized plane, the field near the center and not very far away can be considered as if the plane is infinite.

Perspective view



Edge view

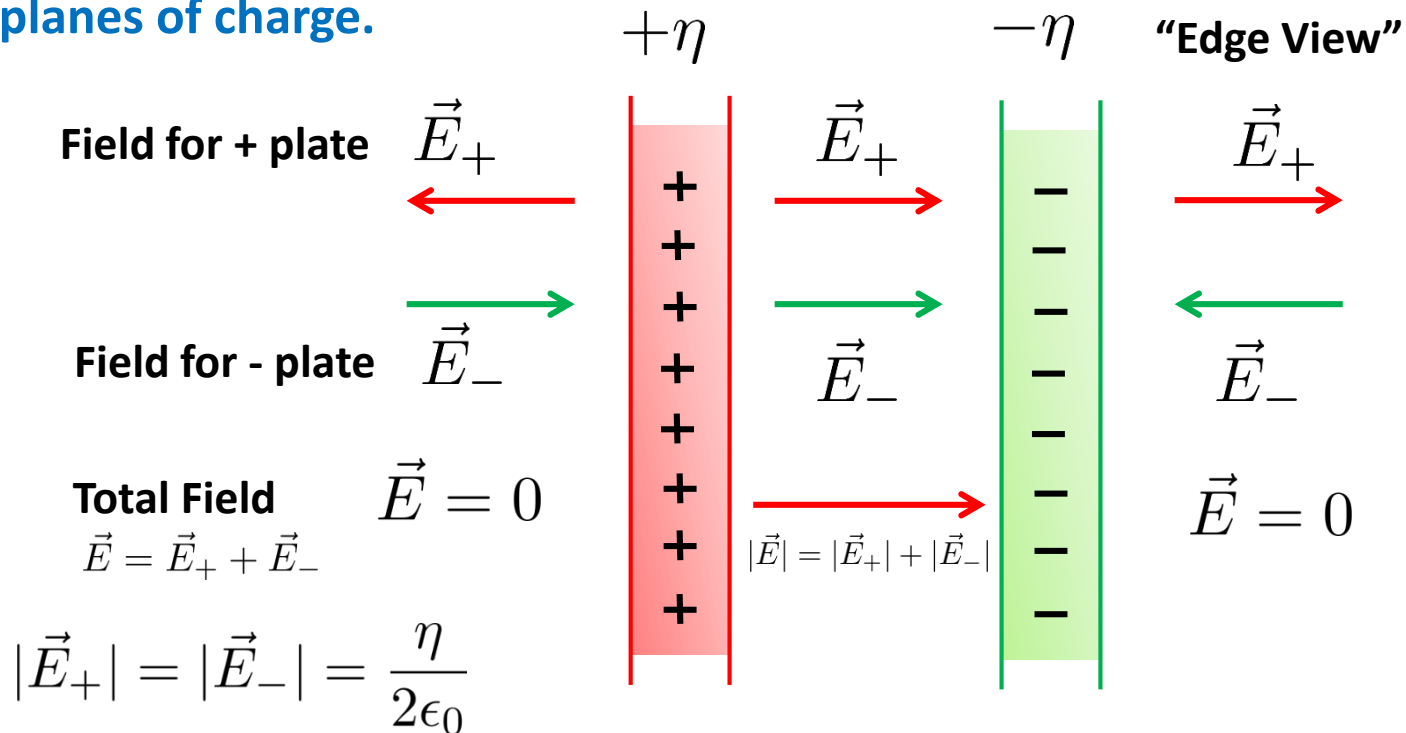


Another Really Important Field Results

The Parallel Plate Capacitor:

In a few weeks, we will study basic circuits, and there we will introduce the capacitor. For now, we will just use the **parallel plate capacitor as a source of uniform electric field**.

An Ideal Parallel Plate Capacitor is made of two equal but oppositely charged infinite planes of charge.



So, between the plates:

$$\vec{E} = \left\{ \frac{\eta}{\epsilon_0}, \text{positive} \rightarrow \text{negative} \right\}$$

Whiteboard Problem: 23-5

When the electric field strength reaches $\sim 3.0 \times 10^6 \text{ N/C}$ in air, the air will “break down” which causes a spark of moving electrons. *This is what happens when you walk across a carpet and touch something, like a doorknob, and get a shock.*

Pikachu creates a strong enough electric field to discharge in air.



Model Pikachu and Ash as an ideal parallel plate capacitor made from two 80.0 cm X 80.0 cm square disks – one is Pikachu, the other is Ash.

What charge should Pikachu and Ash have to create a spark between them? (LC)

The Parallel Plate Capacitor:

$$\vec{E} = \left\{ \frac{\eta}{\epsilon_0}, \text{positive} \rightarrow \text{negative} \right\}$$

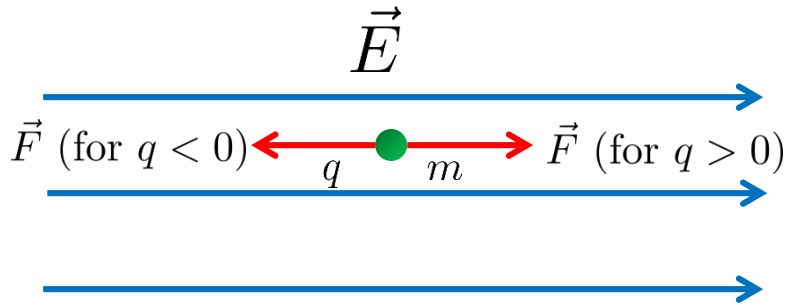
23-3: Motion of Charges in (external) Electric Fields

Up to this point, we have concentrated on the question:

How does charge create electric field?

Now, we want to address: **how do charges move in an External Electric Field.**

Uniform Electric Field (constant in magnitude and direction):



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

From PHY181 & Newton's 2nd Law:

$$\vec{a} = \frac{\vec{F}}{m} = \frac{q}{m}\vec{E} = \text{constant}$$

So, if we want to find the motion of the charge, **we use all of the constant acceleration kinematics (1D & 2D) stuff** that we learned in chapters 2 & 4:



$$x_1 = x_0 + v_0\Delta t + \frac{1}{2}a(\Delta t)^2$$

$$v_1 = v_0 + a\Delta t$$

$$v_1^2 = v_0^2 + 2a\Delta x$$

$$\Delta t = t_1 - t_0$$

$$\Delta x = x_1 - x_0$$

These equations are on the PHY182 equation sheet - at the top of page 1.

Whiteboard Problem: 23-6

An electron in a uniform electric field increases its speed from 2.0×10^7 m/s to 4.0×10^7 m/s over a distance of 1.2 cm.

What is the electric field strength? (LC)

Hint: the mass and charge of the electron are on our constants sheet.

Whiteboard Problem: 23-7

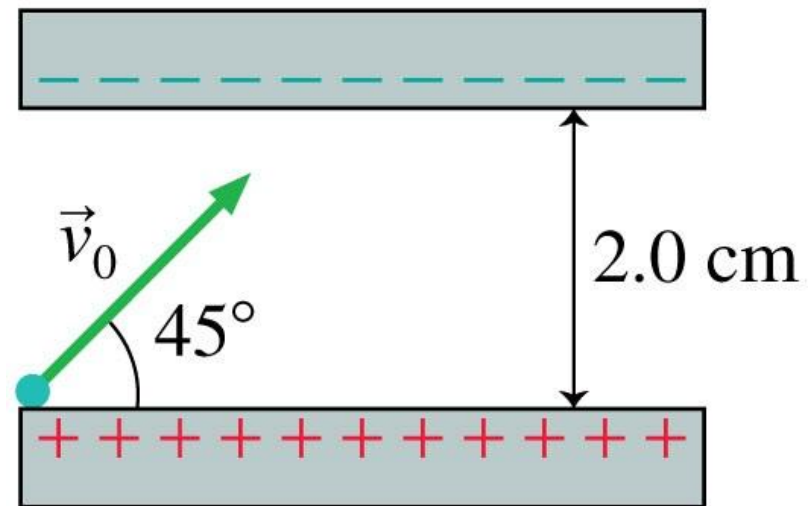
The two parallel plates of a capacitor are 2.0 cm apart, and the electric field strength between them is 1.0×10^4 N/C.

An electron is launched at a 45° angle from the positive plate.

What is the maximum initial speed v_0 the electron can have so that it doesn't hit the negative plate? (LC)

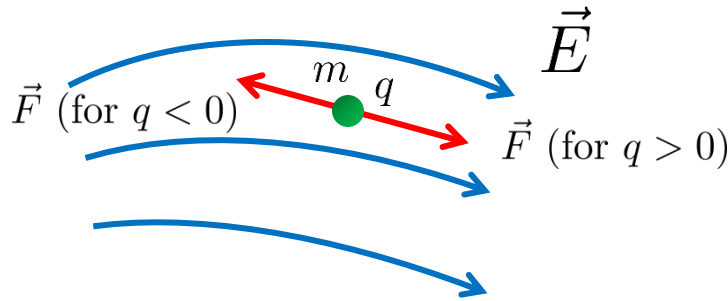
Do we have to include gravity?

No, its effect is minimal; look at the accelerations.



Motion of Charges in (external) Electric Fields

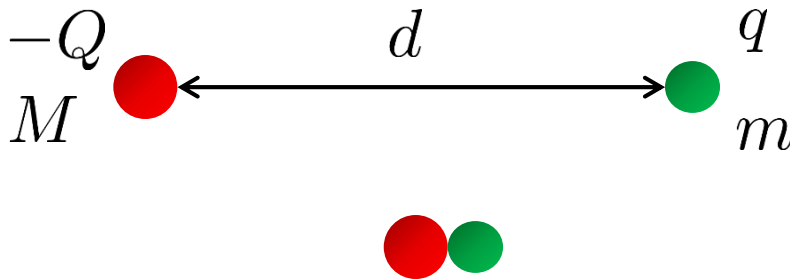
Non-Uniform Electric Field (Not constant in magnitude and/or direction):



Here: $\vec{F} = m\vec{a} = q\vec{E}$
 But: $\vec{a} = \frac{d^2\vec{r}}{dt^2} = \frac{q}{m}\vec{E} \neq \text{constant}$

For this type of problem, the motion has to be integrated (i.e. solve the DE).

But can we do this problem?



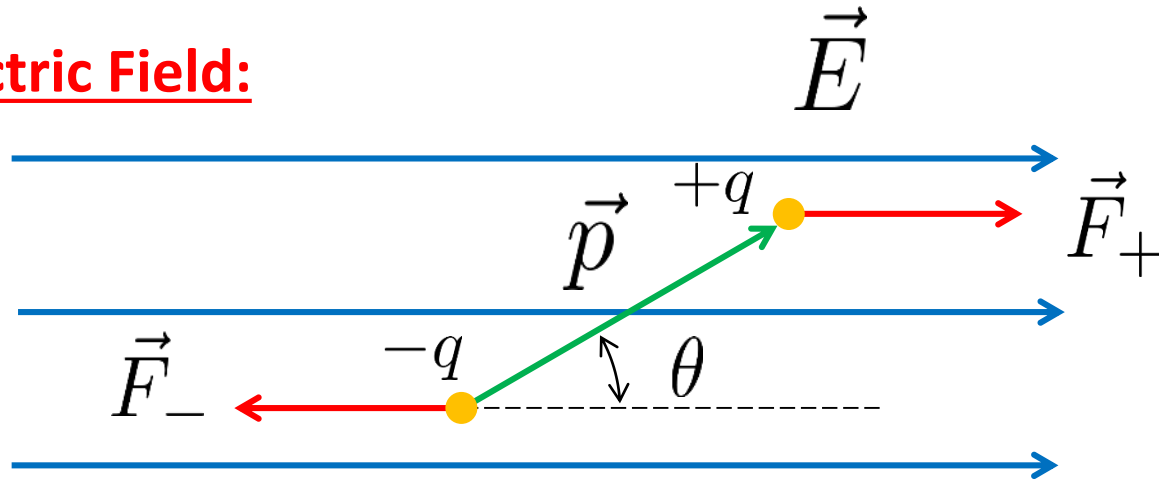
Release charged particles from rest.

What is the impact speed of each particle?

Presently no, the fields and forces are not constant. **But how did we do this for gravity?**
 We used conservation principles – **we'll do the same for the electric force in chapter 25.**

A Dipole Moment in an External Electric Field

Uniform Electric Field:



The **net force** on the dipole:

$$\vec{F}_{\text{net}} = \vec{F}_- + \vec{F}_+ = -q\vec{E} + q\vec{E} = 0$$

But, is the dipole in equilibrium?

No, there is a torque on the dipole. As shown in your text:

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

or

$$|\vec{\tau}| = pE \sin \theta \quad (\text{Direction by RHR})$$

So, the dipole will rotate, but note: the torque is not constant.

How would you describe the motion of a dipole moment in a uniform field? Next WB Problem.

Whiteboard Problem 23-8 (a challenging problem)

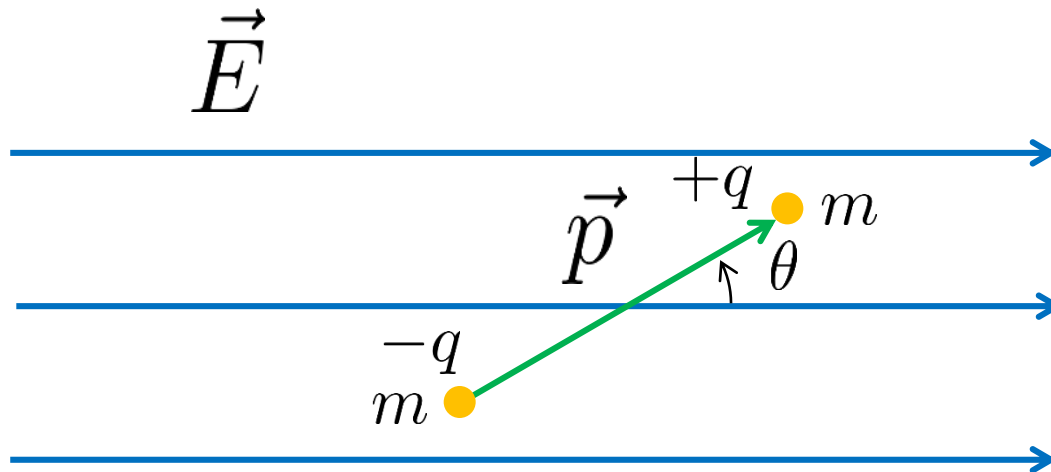
How does a dipole moment move in a uniform electric field?

A dipole moment is made by connecting two objects of mass m and charge $+q$ and $-q$ by a rigid massless rod of length s . The dipole is placed in a uniform electric field of strength E such that the dipole moment is aligned with the field.

The dipole is rotated by a small angle θ and released.

Find an expression for the dipole's period of oscillation in terms of q , s , E , and m . (LC)

Hint: draw it, find the torque, and think back to Chapters 12 & 15.



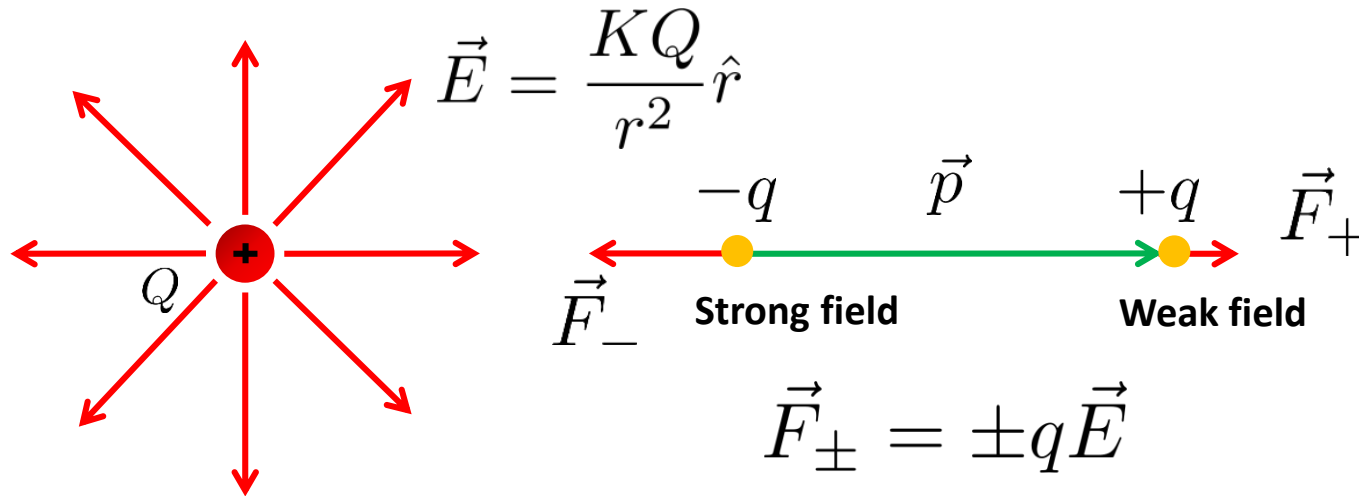
$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$|\vec{\tau}| = pE \sin \theta$$

(Direction by RHR)

A Dipole Moment in an External Electric Field

Non-Uniform Electric Field (e.g. a dipole in the field of a point charge Q):



If the dipole is not aligned with the field, there will be a torque on it, but **for a non-uniform field, there will also be a net force:**

For this orientation, the net force is:

$$\vec{F}_{\text{net}} = \vec{F}_{-} + \vec{F}_{+} = -q\vec{E}(\text{at } -q) + q\vec{E}(\text{at } +q) \neq 0$$

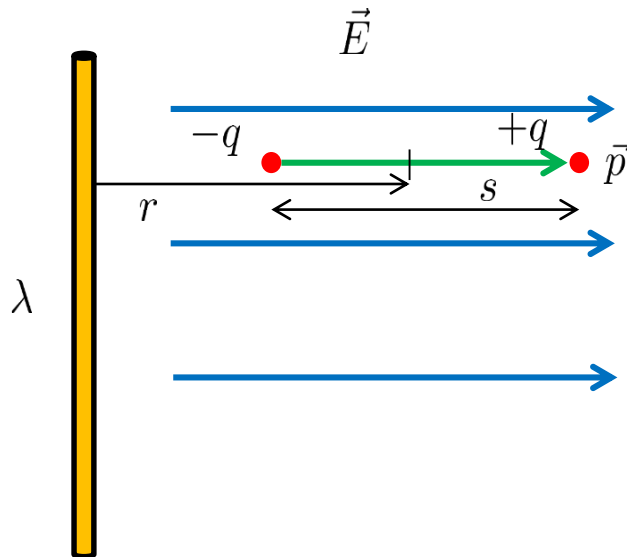
So for this field and orientation, the net force is to the left. What would be the direction of the net force if the dipole was rotated by 180°?
 ... The force would be to the right.

Whiteboard Problem: 23-9

For a dipole moment in an external electric field, there is a stable equilibrium for rotation when \vec{p} is in the same direction as \vec{E} . Consider a dipole moment, \vec{p} , in such an equilibrium orientation in the field of a positive infinite line of charge with linear charge density λ .

a.) Is the force on the dipole attractive, repulsive, or zero? **(LC)**

b.) The distance from the line of charge to the center of the dipole is r and is much larger than the charge separation in the dipole, *i.e.* $r \gg s$. Find an expression for the magnitude of the force on the dipole in terms of p , λ , and r (and constants). **(LC)**



For an infinite line of charge:

$$\vec{E} = \left\{ \begin{array}{l} \frac{2K|\lambda|}{r}, \quad \text{away for } \lambda > 0 \\ \frac{2K|\lambda|}{r}, \quad \text{toward for } \lambda < 0 \end{array} \right\}$$

$\lambda =$ charge per unit length