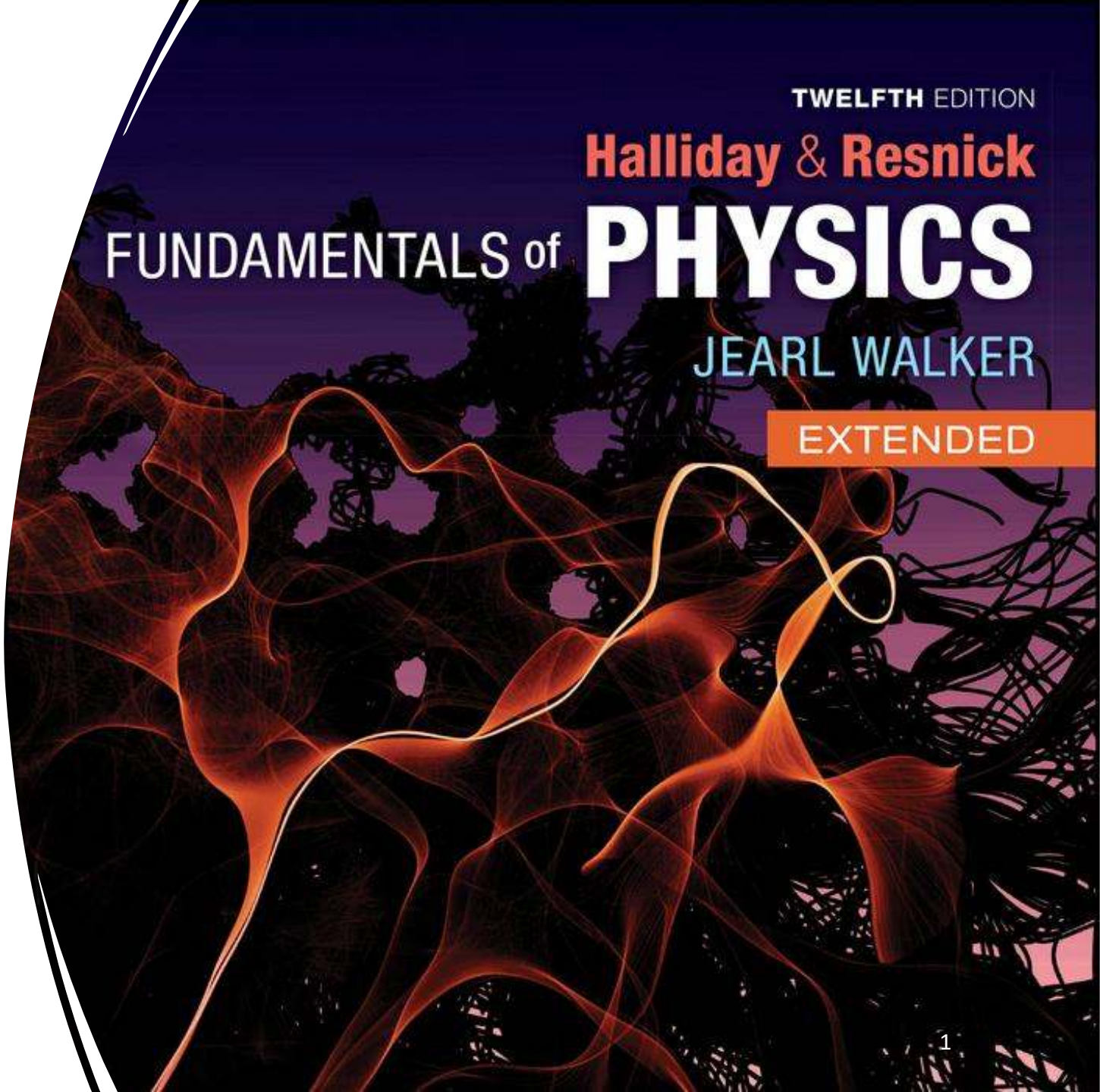
Tue 6 Jan

Chapter 22 Electric Fields

22.1 The electric field

22.2 The electric field due to a charged particle

22.6 A point charge in an electric field



Fundamentals of Physics, Twelfth Edition.
Halliday & Resnick, Walker

Section 22.1 **The Electric Field**

Electrostatic Forces at a Distance

Charge distub place around, and feel presence of e field



How does particle 1 “know” of the presence of particle 2? That is, since the particles do not touch, how can particle 2 push on particle 1—how can there be such an action at a distance?

will be asked about it again

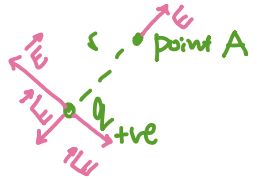
Field: disturbance

PH4105: gravitational field
↳ for every mass
↳ disturb space around it → creating field

* Doesn't disturb itself *

presence of charge creates an electric field
magnet creates magnetic field
me earth

Charge : q W = mg
minimum 2 things (pairs)

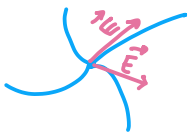


electric field at point A

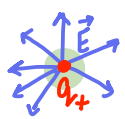
$$E_A = \frac{K|q|}{r^2} \quad \left(\frac{N}{C}\right)$$

r^2 → m^2

* Electric field lines never intersect *



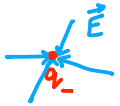
E field start from charge to ∞

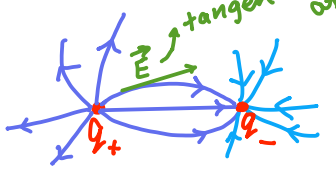


strong electric field ↳ close

also lines close so strong

E field from ∞ to charge





Wed 7 Jan

asked about it 100%

F = mg

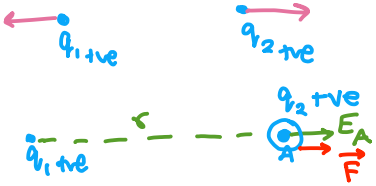
$\vec{F} = q\vec{E}$

[given q & E & direction
Find direction $\vec{F}$]



q_{+ve}
$\vec{F} \propto \vec{E}$
same direction

q_{-ve}
$\vec{F} \propto \vec{E}$
opposite direction

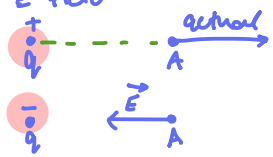


Force on $q_2 = q_2 \times E_A$

$= \frac{q_2 K|q_1|}{r^2}$

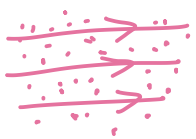
$= \frac{K|q_1 q_2|}{r^2}$

E field due to a point charge



mistake is to draw on q_1
rather must be on point
since charge doesn't disturb itself

Uniform electric field
field lines : parallel & = magnitude



Electrostatic Forces at a Distance



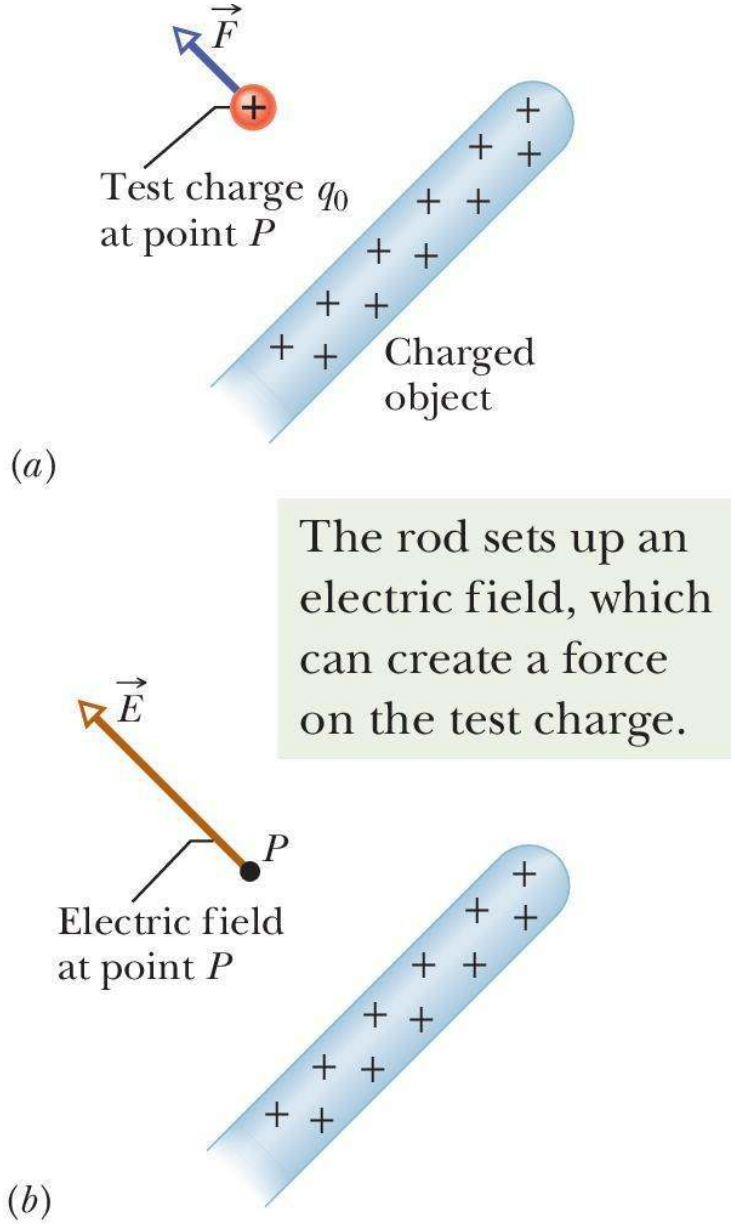
- The explanation is this: Particle 2 sets up an electric field at all points in the surrounding space, even if the space is a vacuum
- If we place particle 1 at any point in that space, particle 1 knows of the presence of particle 2 because it is affected by the electric field particle 2 has already set up at that point.
- Thus, particle 2 pushes on particle 1, but not by touching it as you would push on a coffee mug. Instead, particle 2 pushes by means of the electric field it has set up.

Electric Field Vector Expression

The electric field $\vec{E}$ at any point is defined in terms of the electrostatic force $\vec{F}$ that would be exerted on a positive test charge q_0 placed there:

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_0}$$

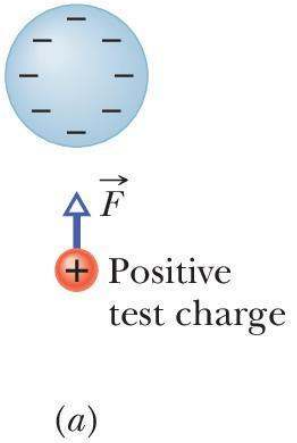
SI unit: N/C

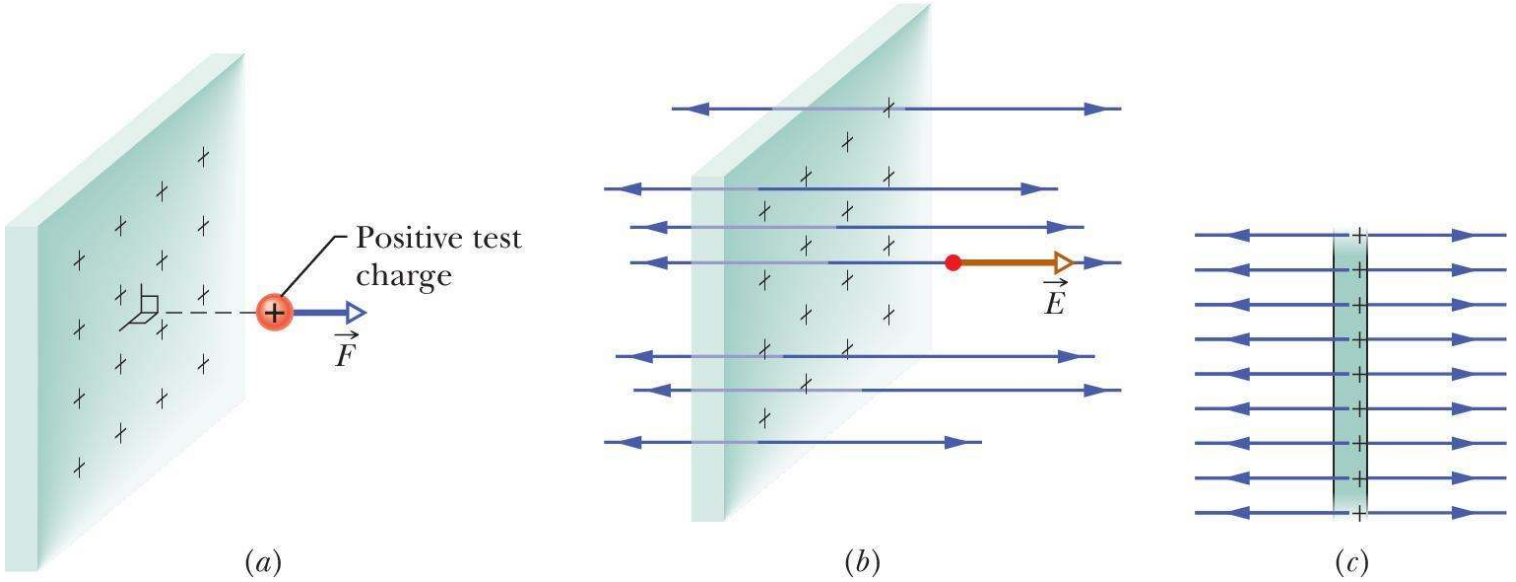


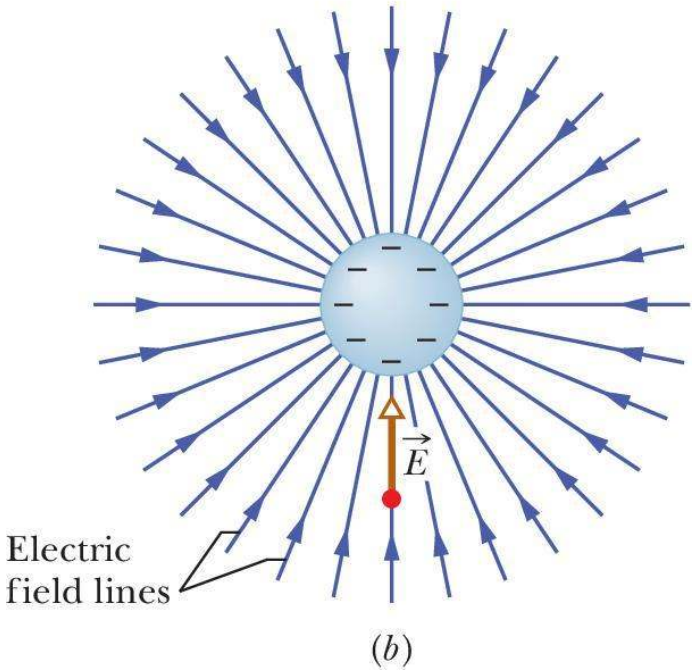
Electric Field Lines

Electric field lines help us visualize the direction and magnitude of electric fields.

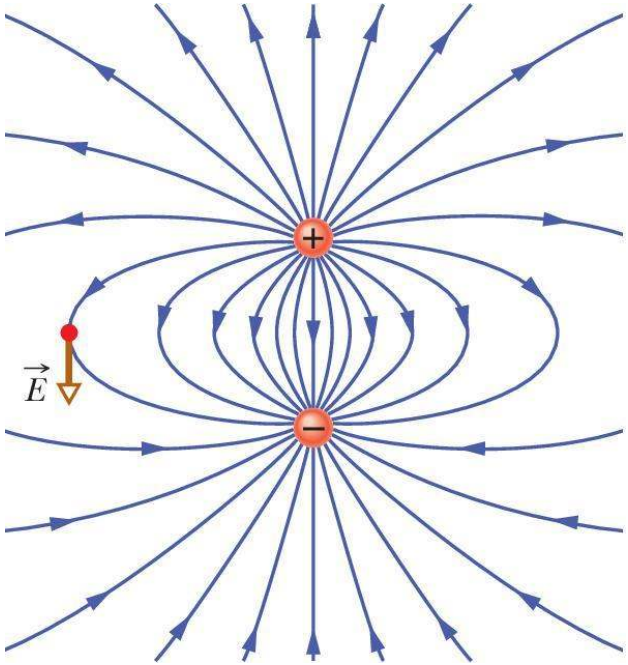
1. The electric field vector at any point is tangent to the field line through that point and in the same direction.

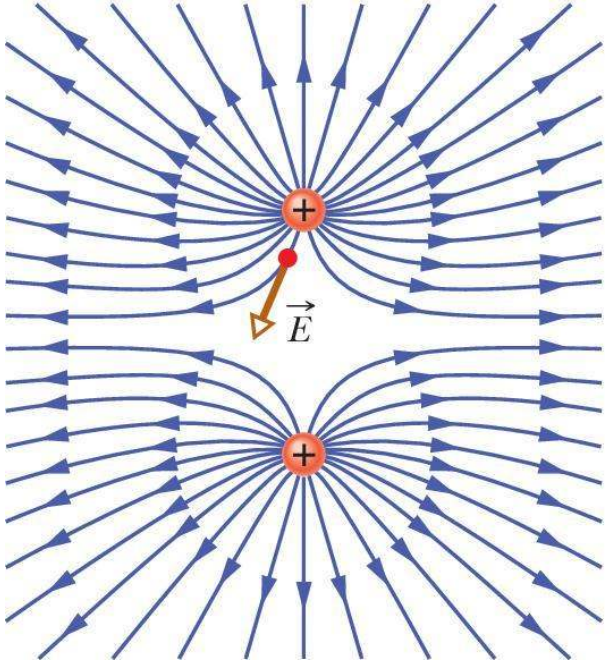




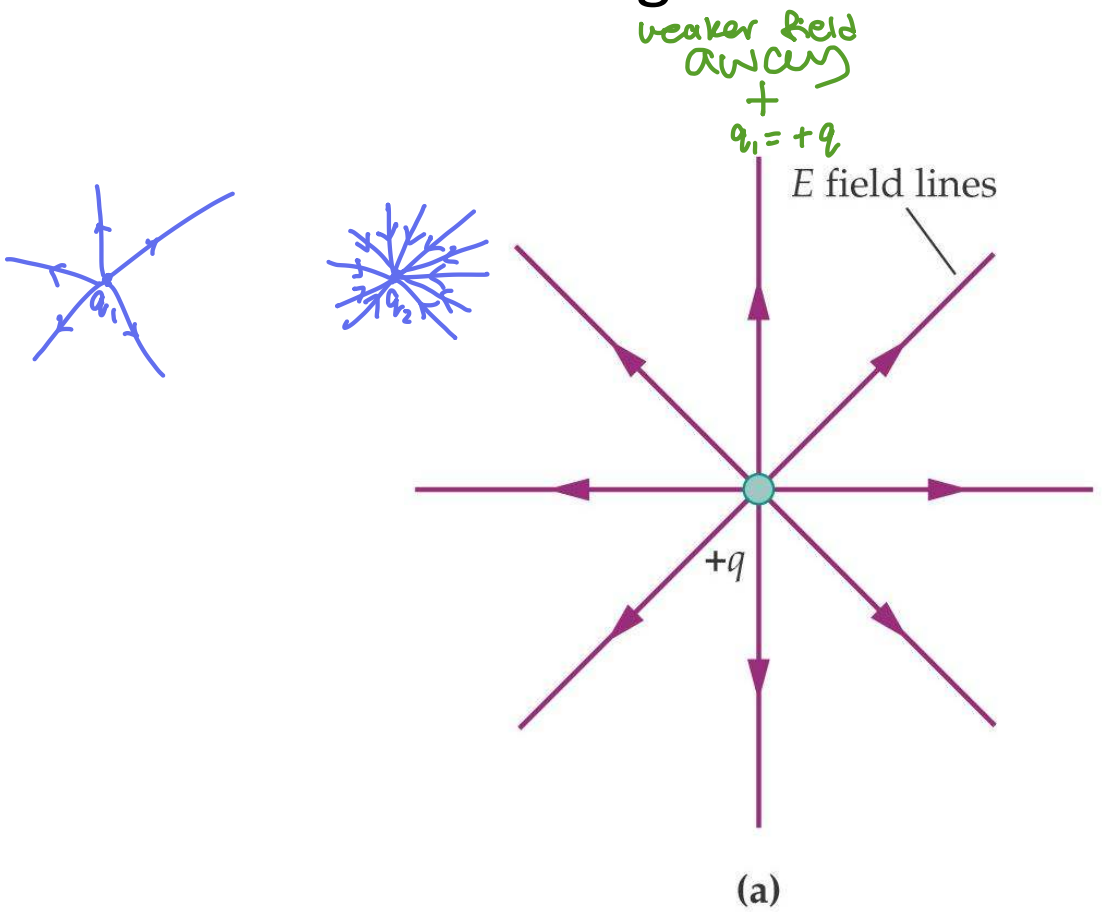


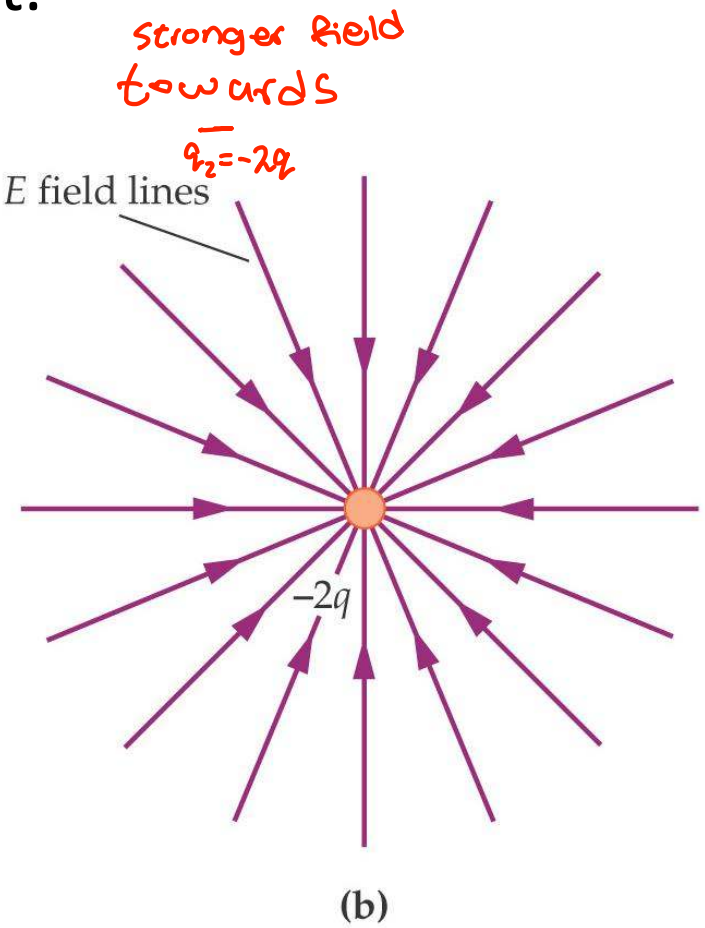
2. The density of field lines in that region is proportional to the magnitude of the electric field there. A closer spacing means a larger field magnitude
3. Electric field lines extend away from positive charge (where they originate) and toward negative charge (where they terminate).

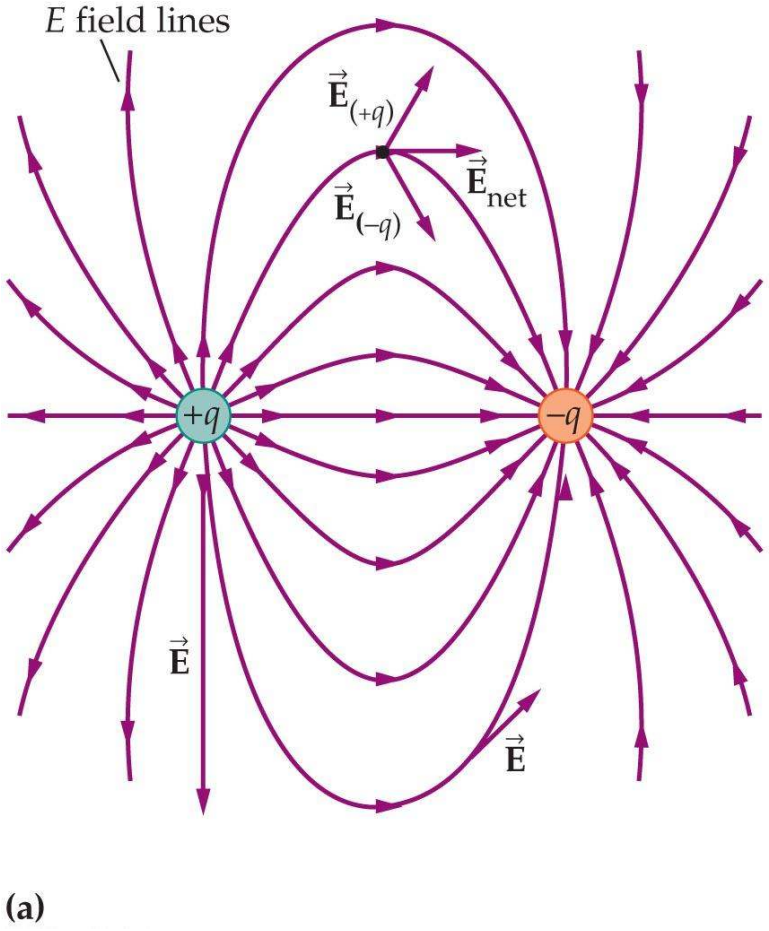




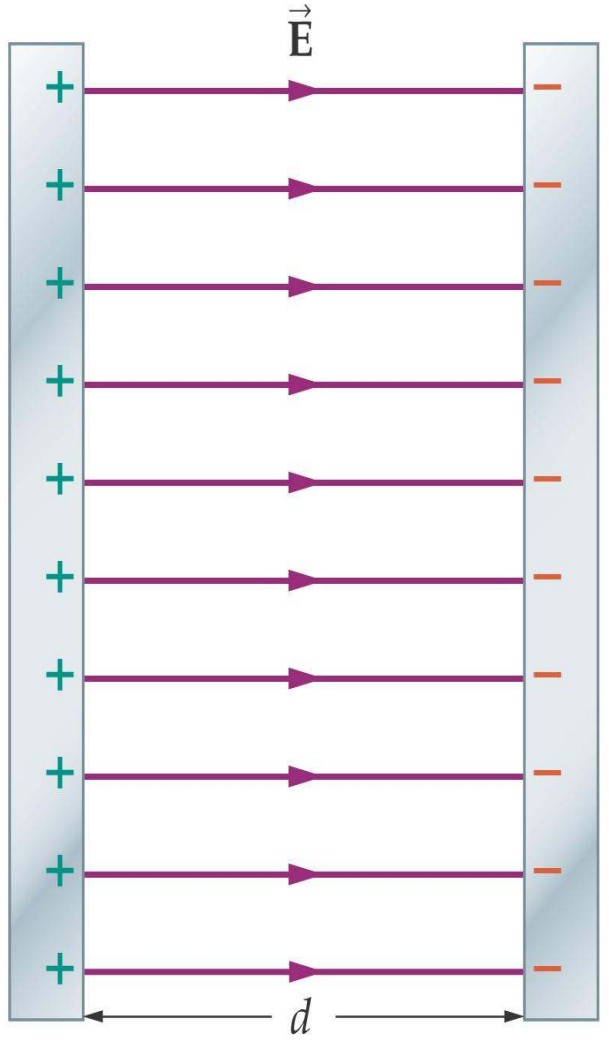
The charge on the right has twice the magnitude of the charge on the left (and opposite in sign), so there are twice as many field lines, and they point towards the charge rather than away from it.







- The electric field around a dipole



- A uniform Electric field: same magnitude and direction at every point within the field

Exercise: The electric field lines surrounding three charges are shown in the figure. The charge at the center is $q_2 = -10.0\ \mu C$

a) What is the sign of q_1 and q_3?

b) Find q_1

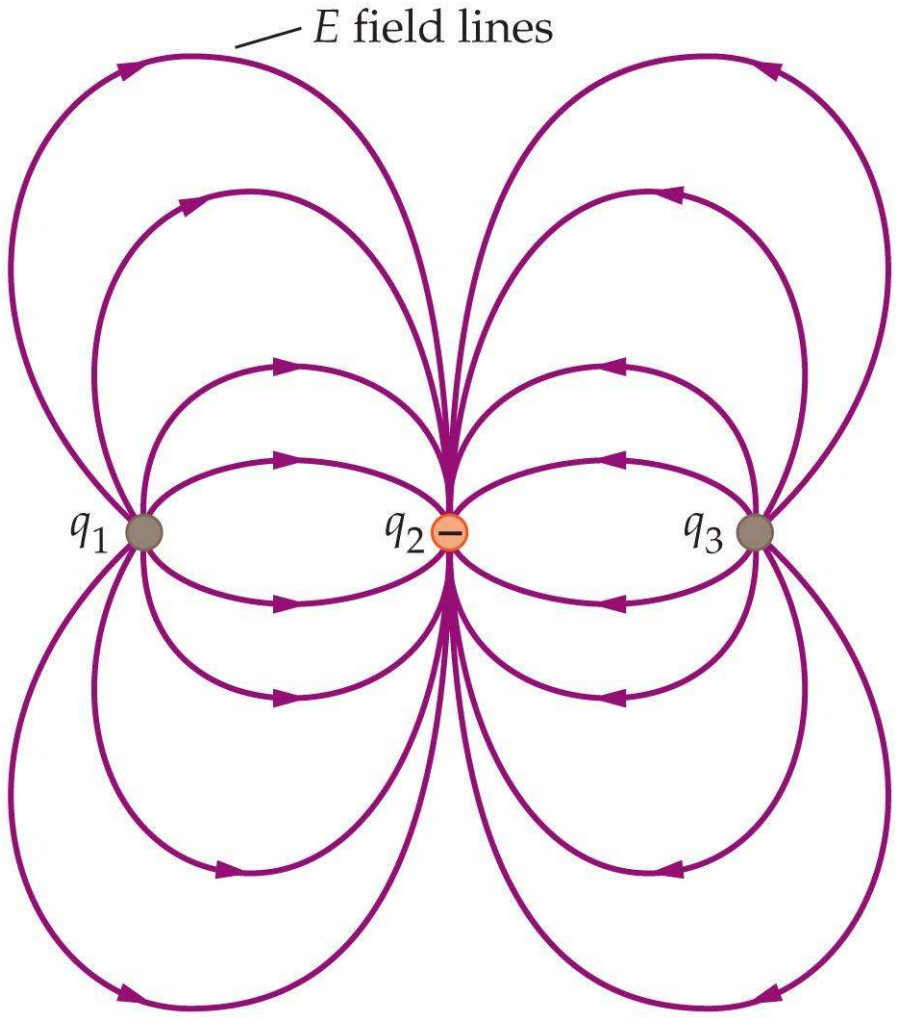
c) Find q_3

8 lines away from q_1 & q_3 so can label it as q but q_2 is opp sign (-) & double number so $-2q$

$q_1 = +q$ $+5\mu C$

$q_2 = -2q$ $= -10\mu C$

$q_3 = +q$ $+5\mu C$



Solution: (a) The electric field lines begin at q_1 and q_3 and end at q_2. The rules of drawing electric field lines indicate that the charges q_1 and q_3 **must be positive**.

(b) The charge q_1 has 8 lines leaving it but q_2 has 16 lines entering it. Because 8 is half of 16, and since the number of lines entering or leaving a charge is proportional to the magnitude of the charge, the magnitude of q_1 is **one-half of q_2 (+5 µC)**

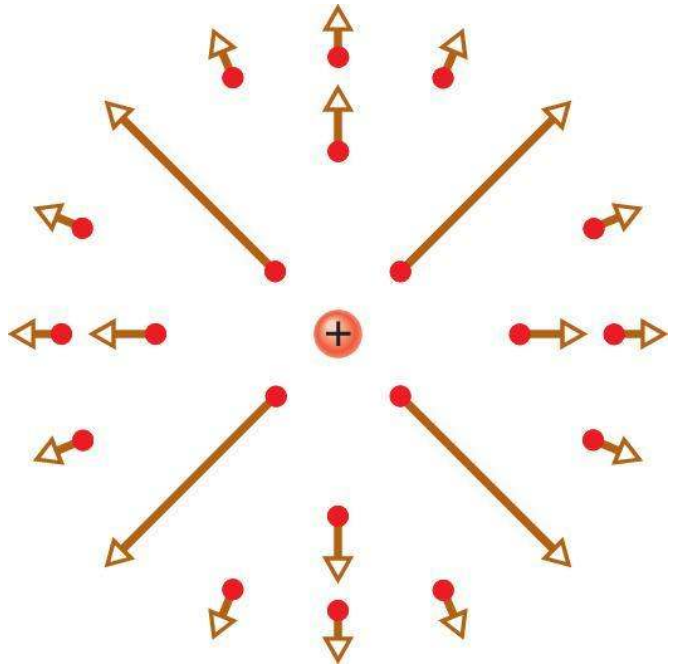
(c) By the same reasoning of part **(b)**, the magnitude of q_3 is **(+5 µC)**

Note: When drawn correctly, an electric field diagram can reveal a wealth of information in a concise approach.

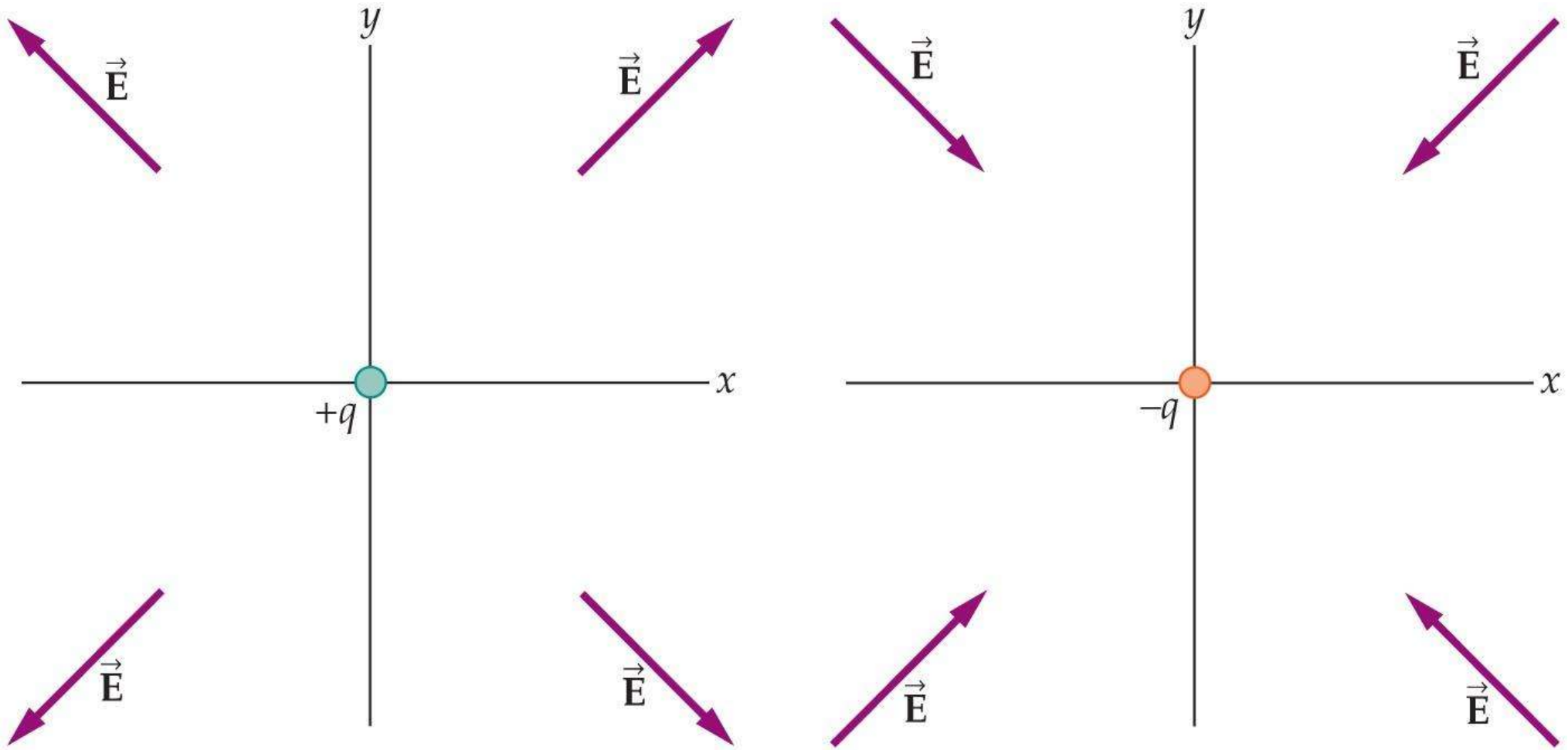
Section 22.2 **The Electric Field Due to a Charged Particle**

The magnitude of the electric field $\vec{E}$ set up by a particle with charge *q* at distance *r* from the particle is

$$E = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$$

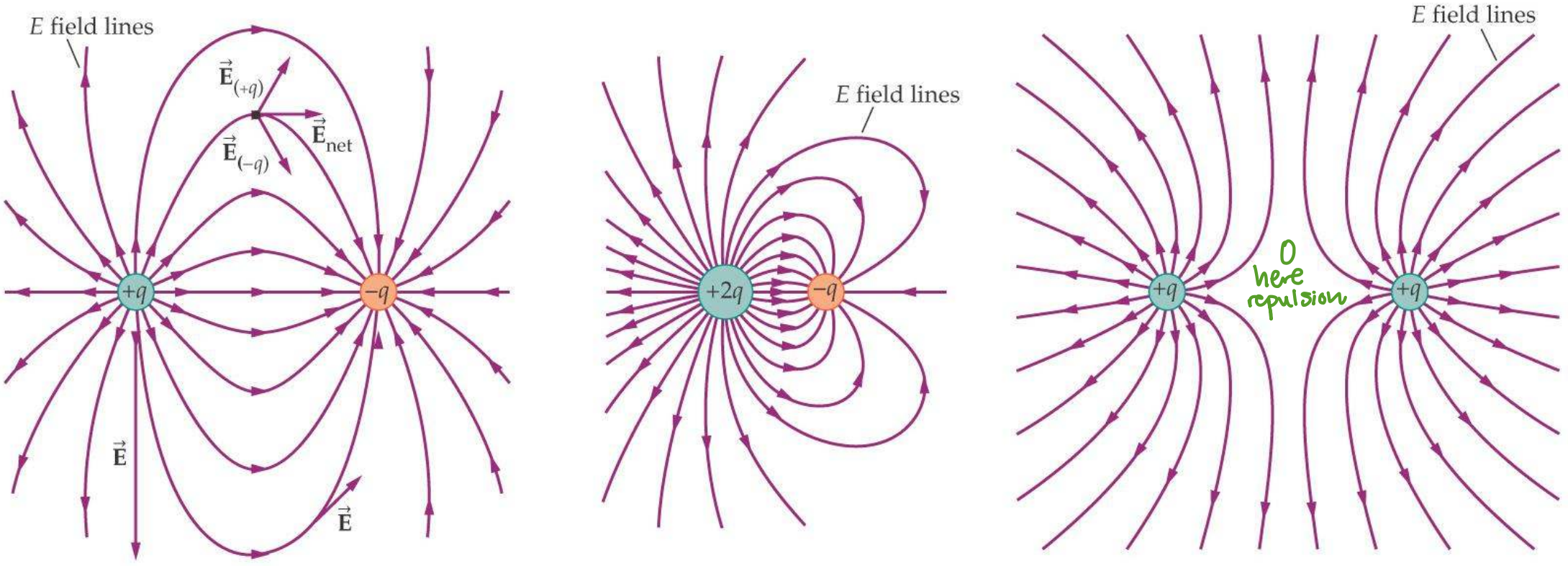


- The **electric field vectors** set up by a positively charged particle all point directly away from the particle.
- Those set up by a negatively charged particle all point directly toward the particle.



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If more than one charged particle sets up an electric field at a point, the net electric field is the vector **sum** of the individual electric fields—**electric fields obey the superposition principle**.



There is only one **point** within the figures above where the **field is zero.** Can you find it?

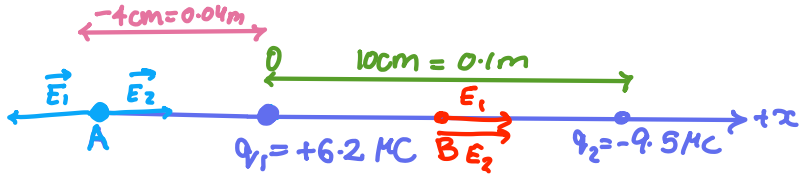
Exercise

Two point-charges lie along the x-axis. A charge of + 6.2 μC is at the origin and a charge of -9.5 μC is placed at a distance x = 10 cm.

What is the net electric field at:

a) x = - 4.0 cm A

b) x = + 4.0 cm B



(a) $E_1 = \frac{K|q_1|}{r^2} = \frac{9\times10^9\,|6.2\times10^{-6}|}{(0.04)^2} = 3.49\times10^7\ \frac{N}{C}(-\hat{x})$ or 34875000

$E_2 = \frac{K|q_2|}{r^2} = \frac{9\times10^9\,|9.5\times10^{-6}|}{(0.14)^2} = 4.36\times10^6\ \frac{N}{C}(+\hat{x})$ or 4362244.8

$E_{net} = -3.49\times10^7 + 4.36\times10^6 = -3.05\times10^7\ \frac{N}{C}(-\hat{x})$

(b) $E_1 = \frac{K q_1}{r^2} = \frac{9\times10^9\,|6.2\times10^{-6}|}{(0.04)^2} = 3.49\times10^7\ \frac{N}{C}(-\hat{x})$

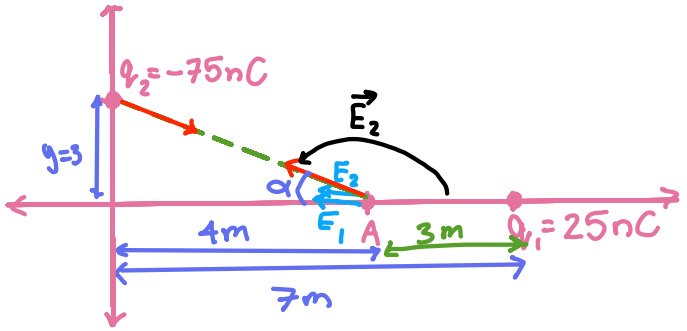
$E_2 = \frac{9\times10^9\,|9.5\times10^{-6}|}{(0.06)^2} = 2.38\times10^7\ \frac{N}{C}$

$E_{net} = 3.49\times10^7 + 2.38\times10^7 = +5.87\times10^7\ \frac{N}{C}(+\hat{x})$

Forces drawn on charge
Field on point

Exercise

A charge of 25 nC is placed on the x-axis at $x = 7$ m and a charge of -75 nC is placed on the y-axis at $y = 3$ m. What is the magnitude and direction of the net electric field produced at the point $x = 4$ m?



$n = 10^{-9}$

$E_1 = \frac{k|q|}{r^2} = \frac{9\times10^9\,|25\times10^{-9}|}{(3)^2} = 25\frac{N}{C}(-\hat{x})$

$E_2 = \frac{k|q|}{r^2} = \frac{9\times10^9\,|75\times10^{-9}|}{(5)^2} = 27\frac{N}{C}$ → pythagorean theorem

$\alpha = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{3}{4}\right) = 37°$

$\vec{E}_2\ (27\frac{N}{C}, 180-37) = (27\frac{N}{C}, 143°)$

$E_{2x} = E_2\cos\alpha = 27\cos(143) = -21.5\frac{N}{C}\ (-\hat{x})$

$E_{2y} = E_2\sin\alpha = 27\sin(143) = 16.25\frac{N}{C}\ (+\hat{y})$

$E_{netx} = -21.5 - 25 = -46.5\frac{N}{C}$

$E_{nety} = 16.25\frac{N}{C}\ (+\hat{y})$

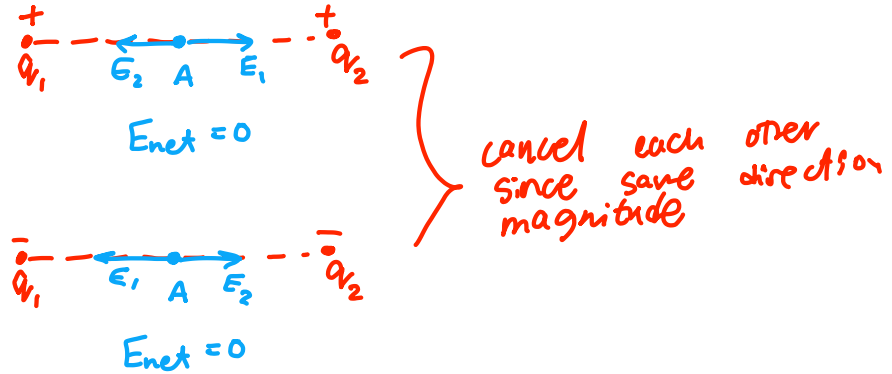
$E_{net} = \sqrt{(E_{netx})^2 + (E_{nety})^2} = 49.27\frac{N}{C}$ | $\theta = \tan^{-1}\left(\frac{16.25}{-46.5}\right) + 180 = 160.83$

3 cases:
1. 1 component
2. Perpendicular
3. forces neither x nor y

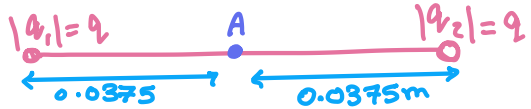
put negative in $\tan^{-1}\left(\frac{y}{-x}\right)$
↳ then add 180

Exercise (HW)

Two point-charges of equal magnitudes are 7.5 cm apart. At the midpoint of the line connecting them, their combined electric field has a magnitude of 45 N/C. Find the magnitude of the charges.



$|q_1| = |q_2| = q$



7.5cm = 0.075m

$E_{net_A} = 45 \frac{N}{C} = E_1 + E_2$

$= K\frac{|q_1|}{r^2} + K\frac{|q_2|}{r^2}$

$= \frac{Kq}{r^2} + \frac{Kq}{r^2}$

$= 2\frac{Kq}{r^2}$

$45 = \frac{2(9\times10^9)q}{(0.0375)^2}$

* solve for q*

$q = 3.5\times10^{-12}\,C$

pico

Solution

The charges must have **opposite signs,** or their electric fields would cancel out at the point midway between them.

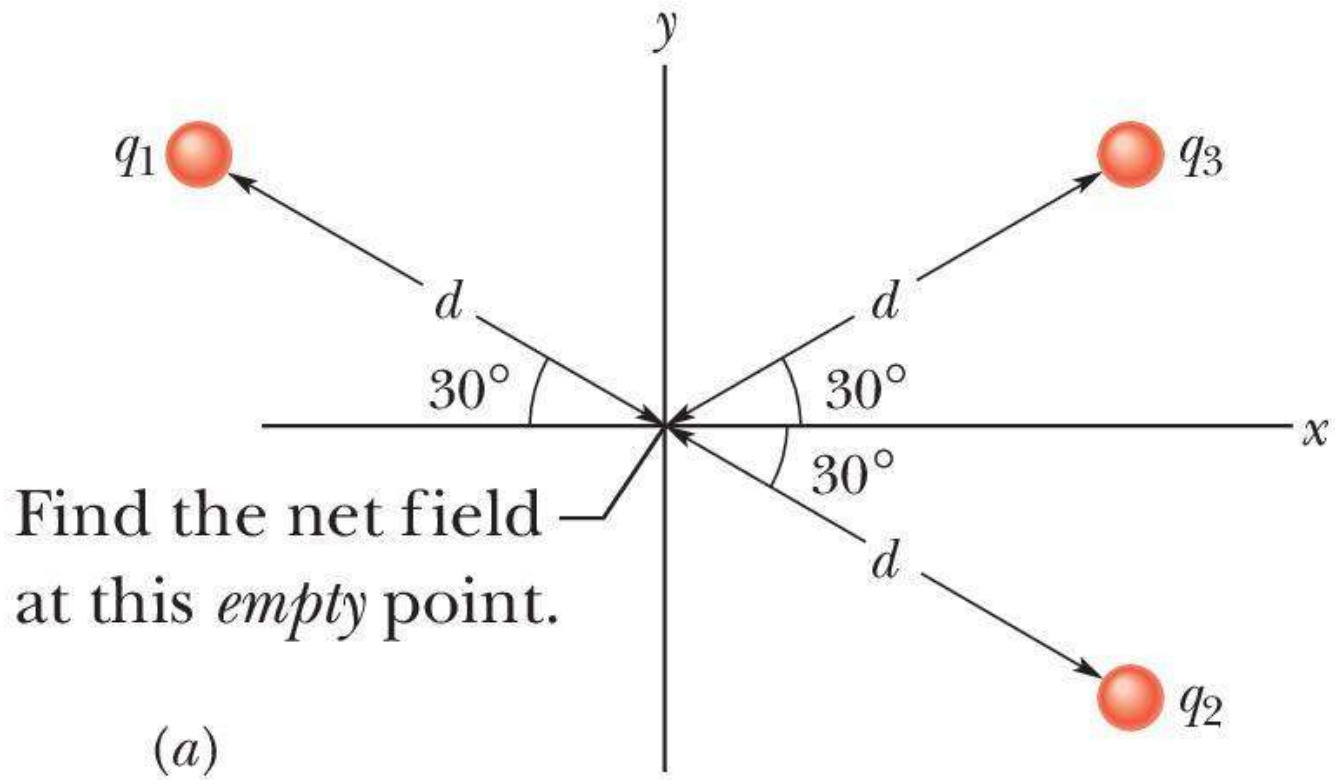
- $\mathbf{E}_{tot} = E_{q1} + E_{q2} = 2\,E_q = 45$ (but remember that electric fields are vectors)
- $22.5 = k\,|q| \,/\, (3.75 \times 10^{-2})^2$

Then,

$|q| = 3.52 \times 10^{-12}\ C$

Extra Home Practice

Find the net electric field at the origin.
Given $q_1 = +2Q, q_2 = -2Q$, and $q_3 = -4Q$



Section 22.6 **Force on a Point Charge in an Electric Field**

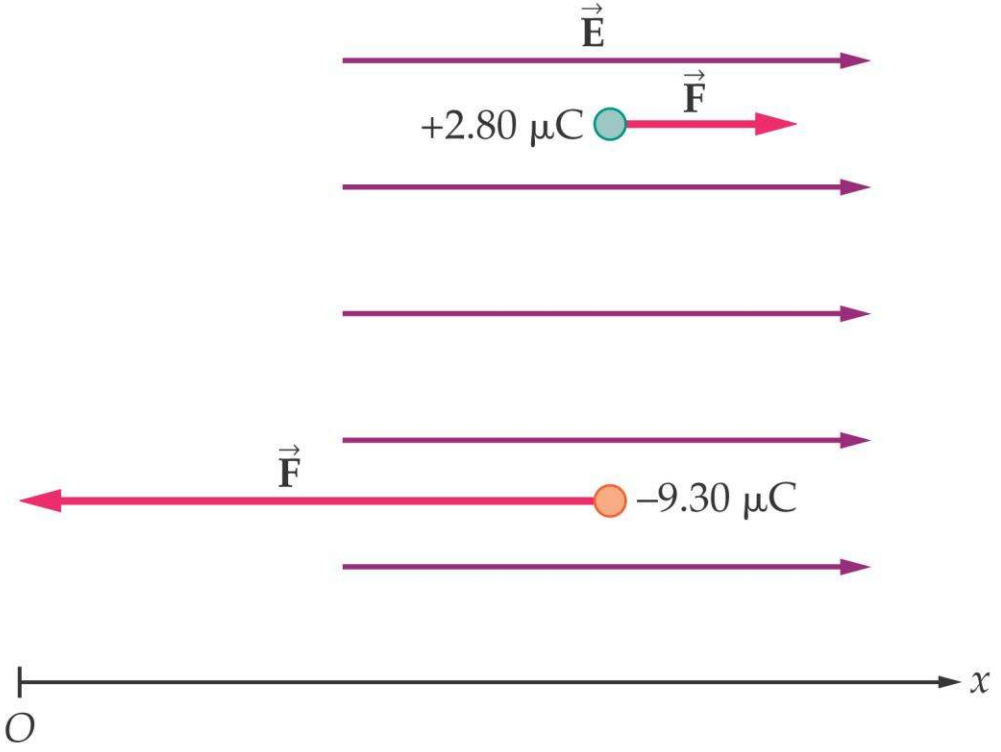
- If a particle with charge q is placed in an external electric field $\vec{E}$, an electrostatic force $\vec{F}$ acts on the particle:

same + direction

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

opposite − direction

- The force acting on the charged particle has the same direction of $\vec{E}$ if the charge of the particle q is positive, and has the opposite direction if the charge q is negative



Exercise: A $+5.0$ µC charge experiences a 0.44 N force in the positive y-direction. If this charge is replaced with a -2.7 µC charge, what force will it experience?

$F = Eq$

$q_1 = +5 \times 10^{-6}\,C$

$F = 0.44\,N$

$\frac{0.44}{5\times10^{-6}} = \frac{E\,(5\times10^{-6})}{5\times10^{-6}}$

$E = 88000\ \frac{N}{C}\ (+y)$

$F = 88000 \times |(-2.7\times10^{-6})|$

$F = 0.2376\ N\ (-y)$

Small space, 1 line (not much detail)

part a → same as question above

part b q_3 added to question after finding Enet find net Force

+ : F & E same direction

− : F & E opposite

$F = |q_3| \times E_A$

Solution:

- Find the electric field:

$$E = F/|q| = 0.44 / (5x10^{-6}) = 8.8 \times 10^{4} (+\hat{y})\ N/C$$

- Now, the force on the second charge is:

$$F = |q|\ E = (2.7 \times 10^{-6}) \times (8.8 \times 10^{4}) = 23.8 \times 10^{-2} => 0.24 (-\hat{y})\ N/C$$

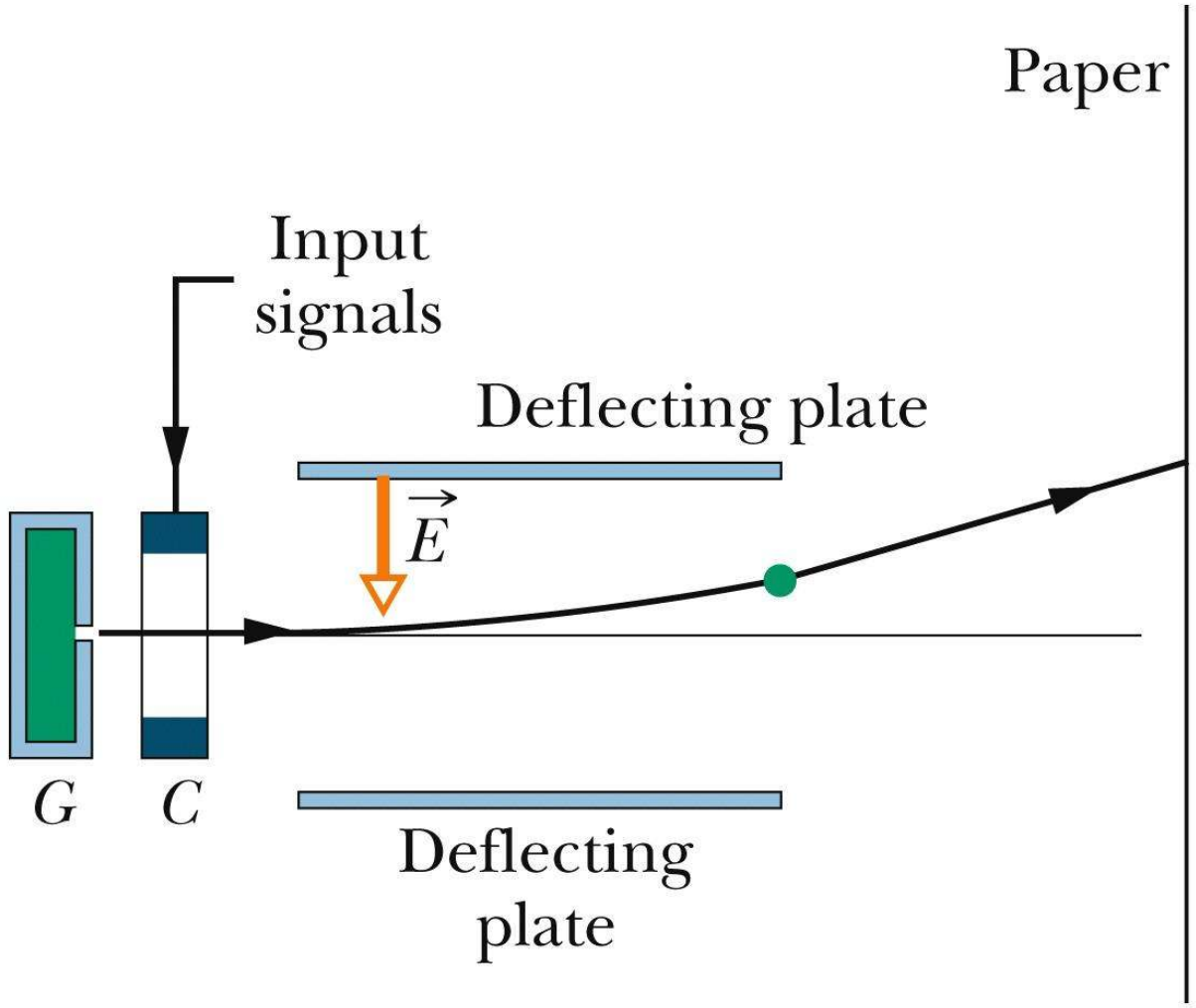
** The **field is exactly the same** at that point **regardless** of

1) **The sign** or

2) Magnitude of **the charge** that is located there.

Ink-jet Printer Application

- Drops shot from generator *G* receive a charge in charging unit *C*. An input signal from a computer controls the charge and thus the effect of field $\vec{E}$ on where the drop lands on the paper.



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- fingerprints (powder)
- car painting
  ↳ maintain consistency