Tuesday January 21

Important Dates

Unit 1

Assignment 1.1 - **Thursday**

Assignment 1.2 - Thursday January 30

Assignment 1.3 - Tuesday February 4

Unit 1 Exam - Thursday February 6

Quiz Thursday

Coulomb's Law

What particle is typically responsible for charge “flow”?

A. Nucleus
B. Proton
C. Neutron
D. Electron

What particle is typically responsible for charge "flow"?

A. Nucleus
B. Proton
C. Neutron
D. Electron

Particle A has a charge of *+3.5* C and is located *0.80* m to the left of particle B. If Particle B carries the same charge as particle A, what is the magnitude and direction of the force experienced by particle B?

A. 1.7×10^{11} N, Away from particle A

B. 4.9×10^{4} N, Away from particle A

C. 1.7×10^{-1} N, Away from particle A

D. 1.7×10^{-1} N, Toward particle A

E. 1.7×10^{11} N, Toward particle A

Particle A has a charge of *+3.5* C and is located *0.80* m to the left of particle B. If Particle B carries the same charge as particle A, what is the magnitude and direction of the force experienced by particle B?

A. 1.7×10^{11} N, Away from particle A

B. 4.9×10^{4} N, Away from particle A

C. 1.7×10^{-1} N, Away from particle A

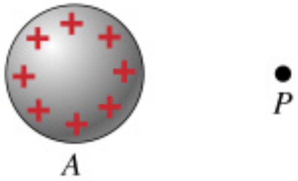
D. 1.7×10^{-1} N, Toward particle A

E. 1.7×10^{11} N, Toward particle A

The Electric Field

(a) How does charged body A exert a force on charged body B?

The Electric Field



(b) Remove body B and label its former position as P

Recall Coulomb's Law

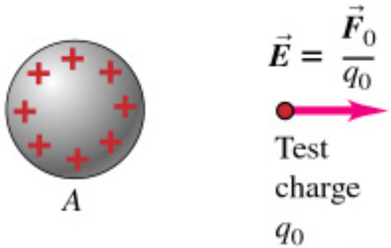
$$\vec{F} = k\frac{q_0 q}{r^2}\hat{r}$$

Rewrite as...

$$\vec{F} = q_0\left(k\frac{q}{r^2}\hat{r}\right)$$

This is the Electric Field vector (due to charge q) at the location of charge q_0

The Electric Field



(c) Body A sets up an electric field $\vec{E}$ at point P:
$\vec{E}$ is the force per unit charge exerted by A on a test charge at P

E units: N/C

E-Field Vector

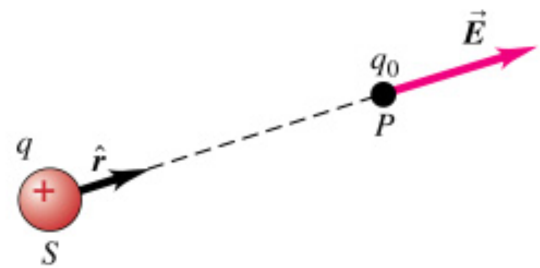
$$\vec{F} = k\frac{q_s q_0}{r^2}\hat{r}$$

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

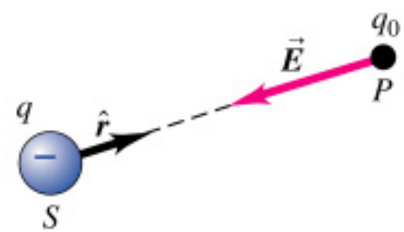
$$\boxed{\vec{E} = k\frac{q_s}{r^2}\hat{r}}$$

This is the Electric Field Due to a Point Charge

(a) Unit vector $\hat{r}$ points from source point S to field point P



(b) At each point P, the electric field set up by an isolated *positive* point charge q points directly *away* from the charge in the *same* direction as $\hat{r}$



(c) At each point P, the electric field set up by an isolated *negative* point charge q points directly *toward* from the charge in the *opposite* direction from $\hat{r}$

What is the magnitude and direction of the electric field 3.5 cm away from a point charge q=+5.0 μC?

A. 1.3×10^{12} N/C, Away from the point charge

B. 1.3×10^{12} N/C, Toward the point charge

C. 3.7×10^{7} N/C, Away from the point charge

D. 3.7×10^{7} N/C, Toward the point charge

E. 1.8×10^{2} N/C, Toward the point charge

What is the magnitude and direction of the electric field 3.5 cm away from a point charge q=+5.0 *micro Coulombs*?

A. 1.3×10^{12} N/C, Away from the point charge

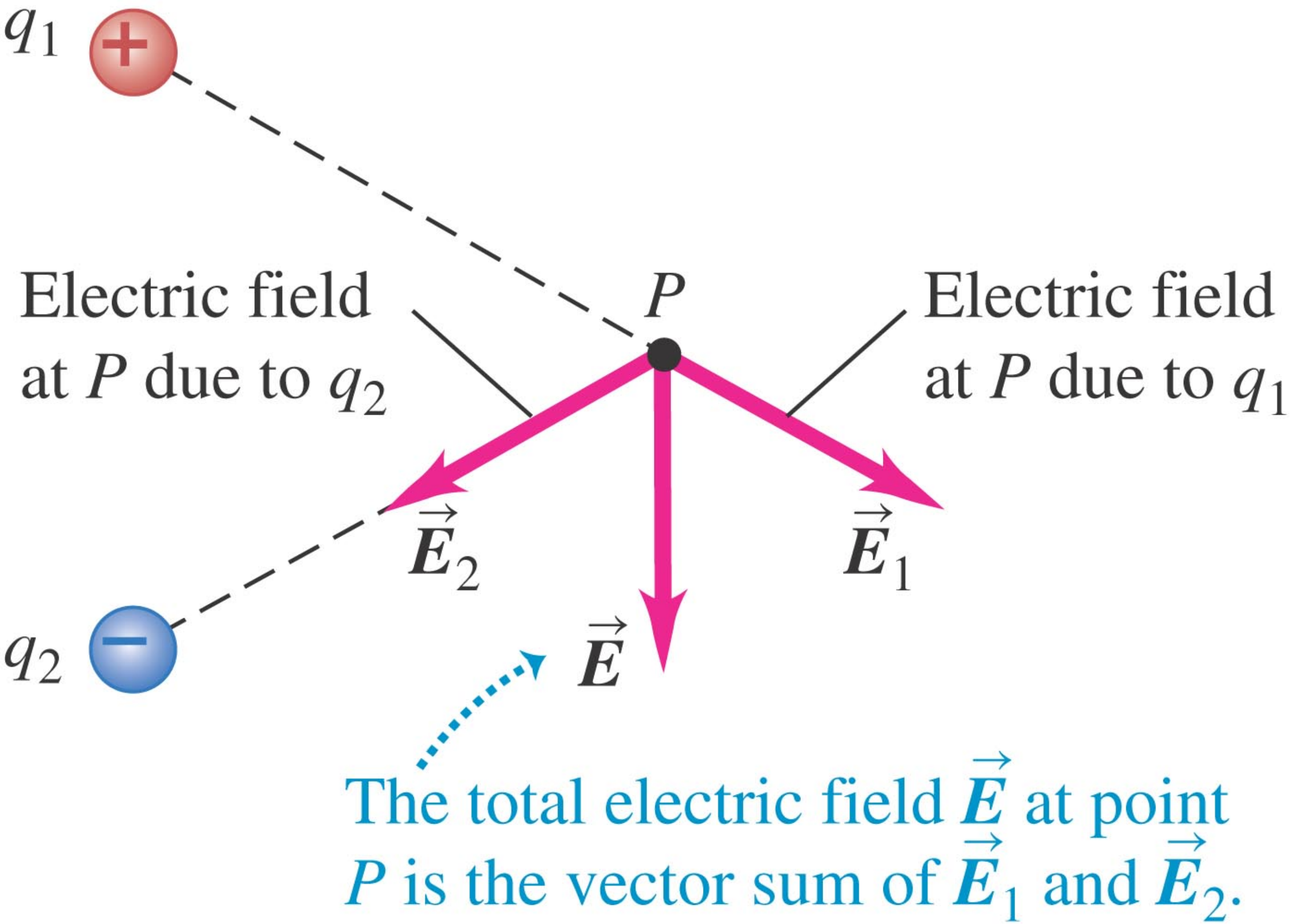
B. 1.3×10^{12} N/C, Toward the point charge

C. 3.7×10^{7} N/C, Away from the point charge

D. 3.7×10^{7} N/C, Toward the point charge

E. 1.8×10^{2} N/C, Toward the point charge

E-Fields Satisfy the **Superposition Principle**



E-Fields Satisfy the **Superposition Principle**

The diagram shows a particle with positive charge Q and a particle with negative charge −Q.

The direction of the electric field at point P on the perpendicular bisector of the line joining them is:

A. ↑

B. ↓

C. →

D. ←

E. zero

E-Fields Satisfy the **Superposition Principle**

The diagram shows a particle with positive charge Q and a particle with negative charge −Q.

The direction of the electric field at point P on the perpendicular bisector of the line joining them is:

A. $\uparrow$

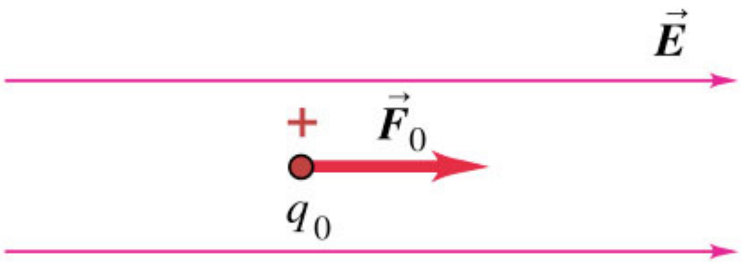
B. $\downarrow$

C. $\longrightarrow$

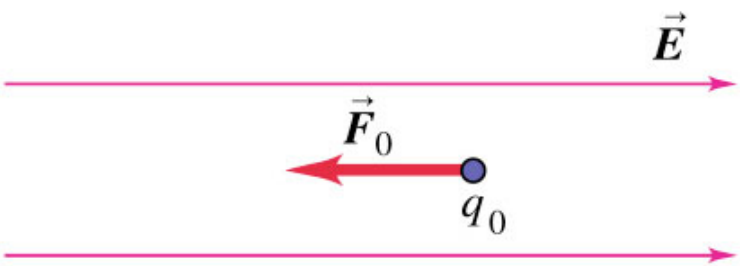
D. $\longleftarrow$

E. zero

Electric Field and Force Vector



(a) Positive charge q_0 placed in an electric field: force on q_0 is in same direction as $\vec{E}$



(b) Negative charge q_0 placed in an electric field: force on q_0 is in opposite direction from $\vec{E}$

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

Continuous Charge Distributions

Charge Distributions

- Linear Charge Density (l)

$$\lambda = \frac{dQ}{dL}$$

$$\lambda = \frac{Q}{L} \quad \text{charge}/\text{length}$$

- Surface Charge Density (s)

$$\sigma = \frac{dQ}{dA}$$

$$\sigma = \frac{Q}{A} \quad \text{charge}/\text{area}$$

- Volume Charge Density (r)

$$\rho = \frac{dQ}{dV}$$

$$\rho = \frac{Q}{V} \quad \text{charge}/\text{volume}$$

A total charge of 6.3×10^{-8} C is distributed uniformly throughout a 2.7 cm radius sphere. The volume charge density is:

A. 3.7×10^{-7} C/m^3

B. 6.9×10^{-6} C/m^3

C. 6.9×10^{-6} C/m^2

D. 2.5×10^{-4} C/m^3

E. 7.6×10^{-4} C/m^3

A total charge of 6.3×10^{-8} C is distributed uniformly throughout a 2.7 cm radius sphere. The volume charge density is:

A. 3.7×10^{-7} C/m^3

B. 6.9×10^{-6} C/m^3

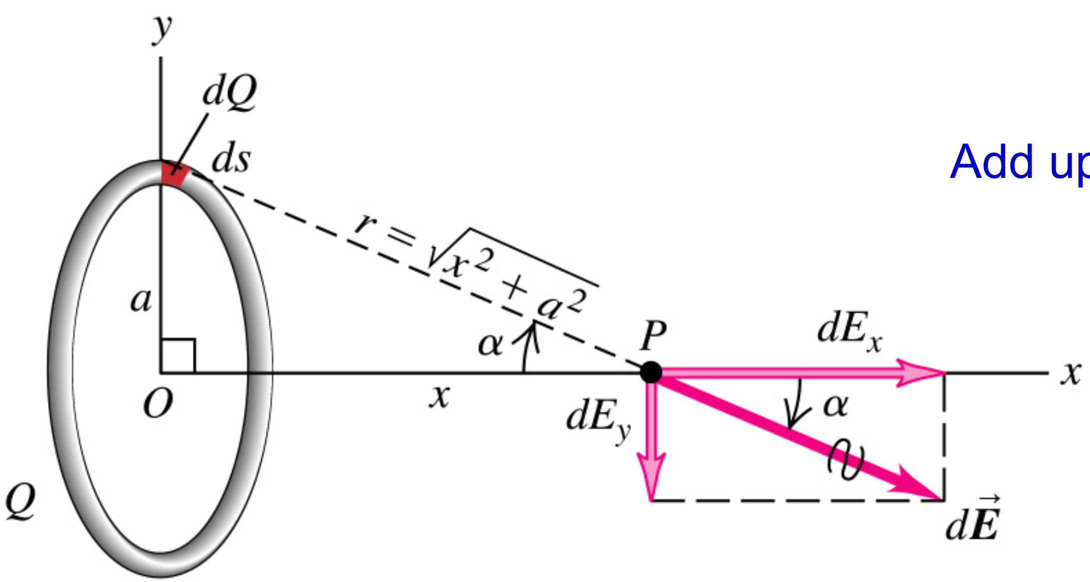
C. 6.9×10^{-6} C/m^2

D. 2.5×10^{-4} C/m^3

E. 7.6×10^{-4} C/m^3

Electric Field Due to a Continuous Charge Distribution

Charged Ring



Consider a 'tiny' part of the ring, dQ.

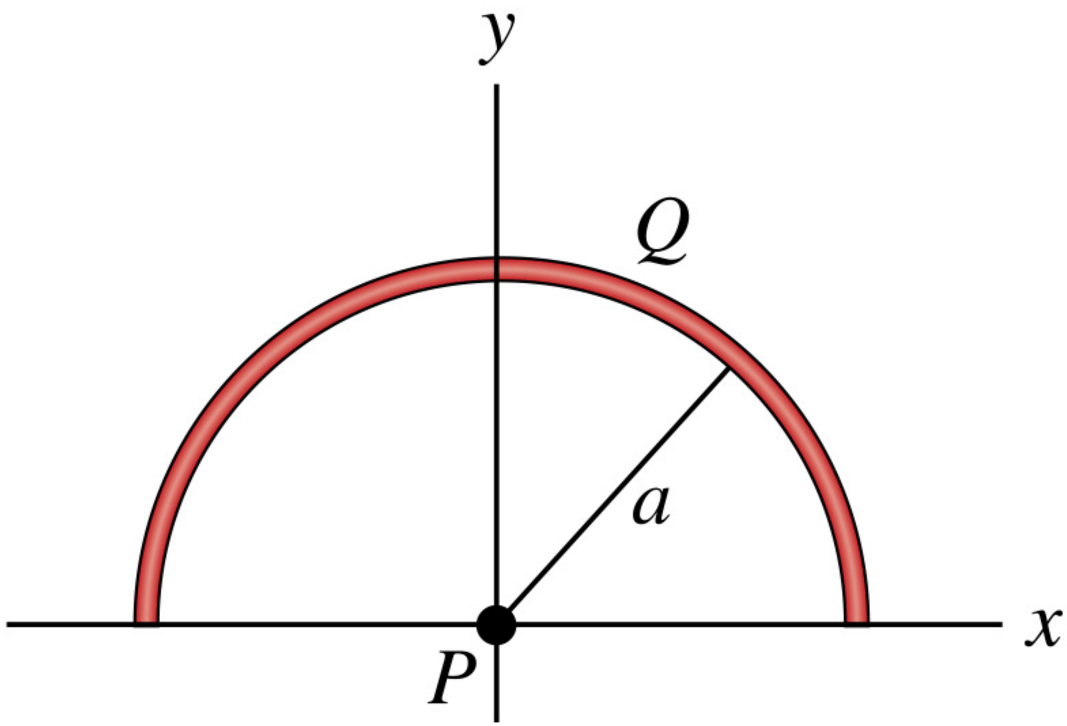
Calculate the field at P due to dQ.

$$dE = \left|dE\right| = k\frac{\left|dQ\right|}{r^2}$$

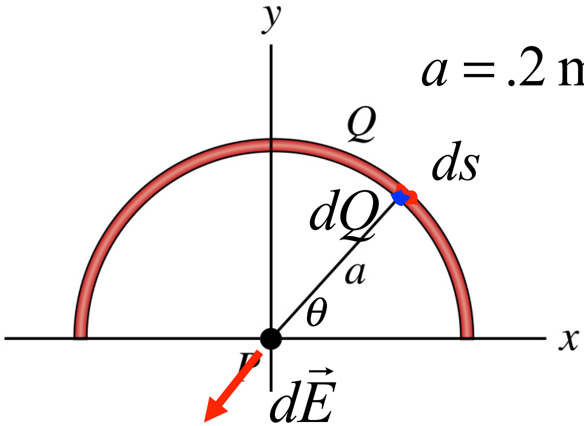
Add up (integrate) these 'tiny' bits.

$$E = \int dE$$

Electric Field Due to a Continuous Charge Distribution



If Q is +0.01 C and a is 0.2 m, what is $\overline{E}$ at P?



$a = .2\text{ m};\ Q = .01\text{ C}$

$$\left|d\vec{E}\right| = k\frac{|dQ|}{a^2}$$

$$d\vec{E} = (dE_x)\hat{i} + (dE_y)\hat{j}$$

$$\vec{E} = \int d\vec{E} = \left(\int dE_x\right)\hat{i} + \left(\int dE_y\right)\hat{j}$$

$$\int dE_x = 0$$

$$dE_y = -dE\sin\theta = -k\frac{|dQ|}{a^2}\sin\theta$$

$$\lambda = \frac{Q}{\pi a} = \frac{dQ}{ds} \Rightarrow dQ = \lambda ds$$

$$dE_y = -k\frac{\lambda ds}{a^2}\sin\theta$$

$$ds = a\,d\theta$$

$$dE_y = -k\frac{\lambda}{a}\sin\theta\,d\theta$$

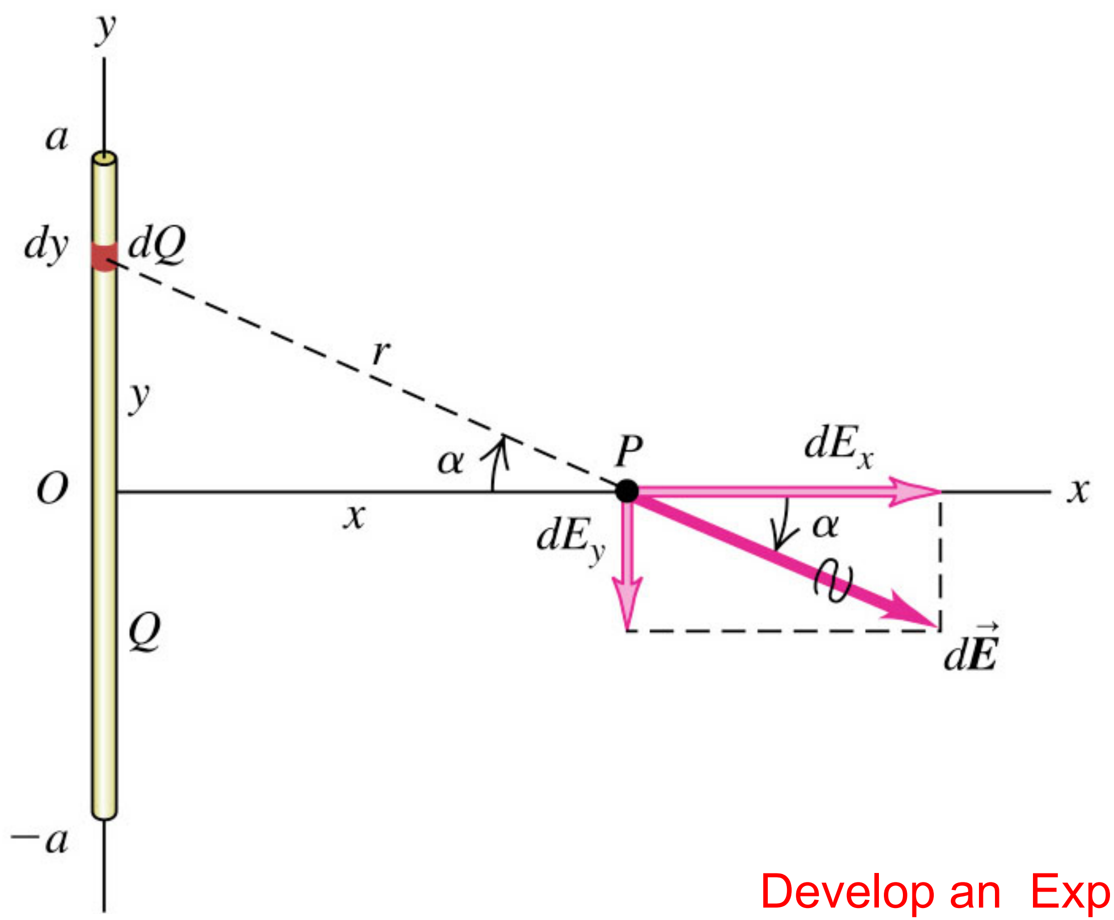
$$E_y = \int dE_y = -k\frac{\lambda}{a}\int_0^\pi \sin\theta\,d\theta$$

$$E_y = -k\frac{\lambda}{a}(-\cos\pi - -\cos 0) = -k\frac{\lambda}{a}(1+1)$$

$$E_y = -2k\frac{\lambda}{a} = -2k\frac{Q}{\pi a^2}$$

$$\boxed{\vec{E} = (E_y)\hat{j} = -2k\frac{Q}{\pi a^2}\hat{j}}$$

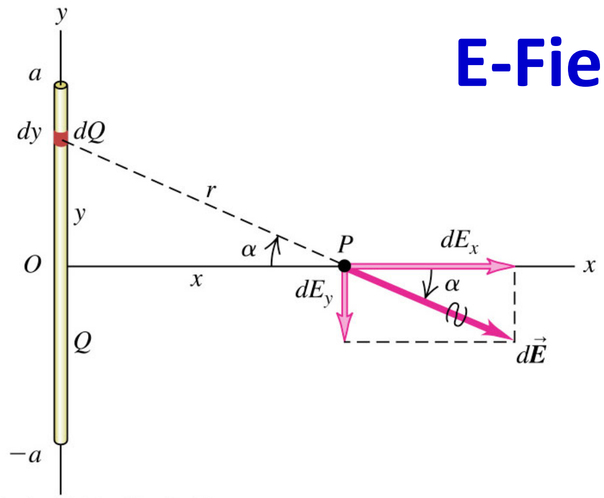
E-Field Due to a Charged Rod



Develop an Expression for E.

Try this one on your own…

E-Field Due to a Charged Rod



$$\left|d\vec{E}\right| = k\frac{|dQ|}{r^2}$$

$$d\vec{E} = (dE_x)\hat{i} + (dE_y)\hat{j}$$

$$\vec{E} = \int d\vec{E} = \left(\int dE_x\right)\hat{i} + \left(\int dE_y\right)\hat{j}$$

$$\int dE_y = 0$$ Symmetry

$$dE_x = dE(\cos\alpha) = k\frac{|dQ|}{r^2}\cos\alpha$$

$$\lambda = \frac{dQ}{dy} = \frac{Q}{2a} \Rightarrow dQ = \frac{Qdy}{2a}$$

$$dE_x = dE(\cos\alpha) = k\frac{Qdy}{2ar^2}\cos\alpha$$

$$r = \left(x^2 + y^2\right)^{1/2}; \quad \cos\alpha = \frac{x}{r}$$

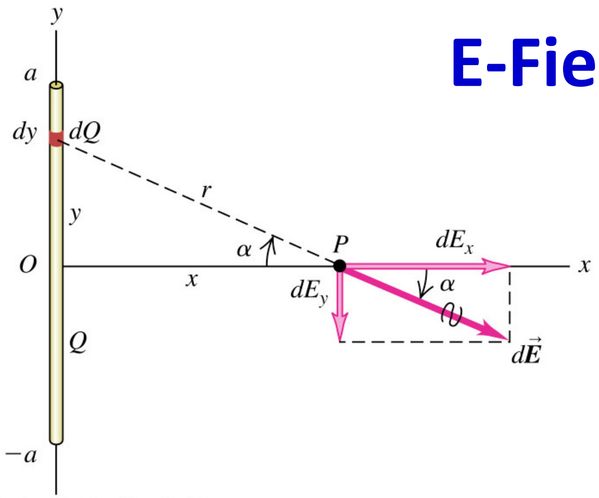
$$dE_x = k\frac{Qdy}{2a\left(x^2+y^2\right)}\frac{x}{\left(x^2+y^2\right)^{1/2}}$$

$$dE_x = \frac{kQx}{2a}\frac{dy}{\left(x^2+y^2\right)^{3/2}}$$

$$E_x = \int dE_x = \frac{kQx}{2a}\int_{-a}^{a}\frac{dy}{\left(x^2+y^2\right)^{3/2}}$$

$$\int_{-a}^{a}\frac{dy}{\left(x^2+y^2\right)^{3/2}} = \left(\frac{y}{x^2\left(x^2+y^2\right)^{1/2}}\right]_{-a}^{a}$$

E-Field Due to a Charged Rod



$$\int_{-a}^{a} \frac{dy}{\left(x^2+y^2\right)^{3/2}} = \left(\frac{y}{x^2\left(x^2+y^2\right)^{1/2}} \right]_{-a}^{a}$$

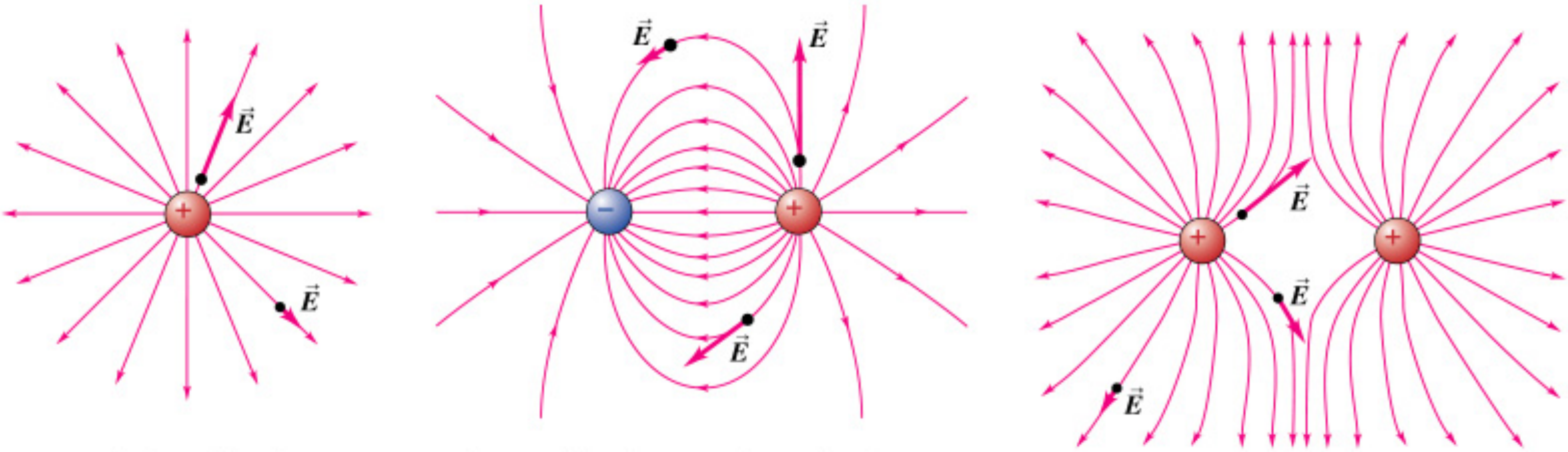
$$E_x = \int dE_x = \frac{kQx}{2a}\left(\frac{y}{x^2\left(x^2+y^2\right)^{1/2}} \right]_{-a}^{a}$$

$$\left(\frac{y}{x^2\left(x^2+y^2\right)^{1/2}} \right]_{-a}^{a} = \frac{a}{x^2\left(x^2+a^2\right)^{1/2}} - \frac{-a}{x^2\left(x^2+(-a)^2\right)^{1/2}}$$

$$E_x = \frac{kQx}{2a}\frac{2a}{x^2\left(x^2+a^2\right)^{1/2}} \qquad E_x = \frac{kQ}{x\left(x^2+a^2\right)^{1/2}}$$

$$\boxed{\vec{E} = \left(E_x\right)\hat{i} + \left(E_y\right)\hat{j} = \left(\frac{kQ}{x\left(x^2+a^2\right)^{1/2}} \right)\hat{i}}$$

E-Field Lines



(a) A single positive charge (compare Figure 21.16)

(b) A positive charge and a negative charge of equal magnitude (an electric dipole)

(c) Two equal positive charges

Electric Field Lines

…The Rules

Electric Fields can be represented by lines/curves.

The local direction of the field line(s) is the direction of the electric field at that point.

The direction of the electric field line gives the direction of the force on a positively charged particle at that point.

The ‘density’ of the field lines is proportional to the strength of the electric field.

Electric Field lines begin on positive charges and end on negative charges.

Electric Field Lines never cross.

What would it mean if they did?

Lab #2

Electric Field Lines