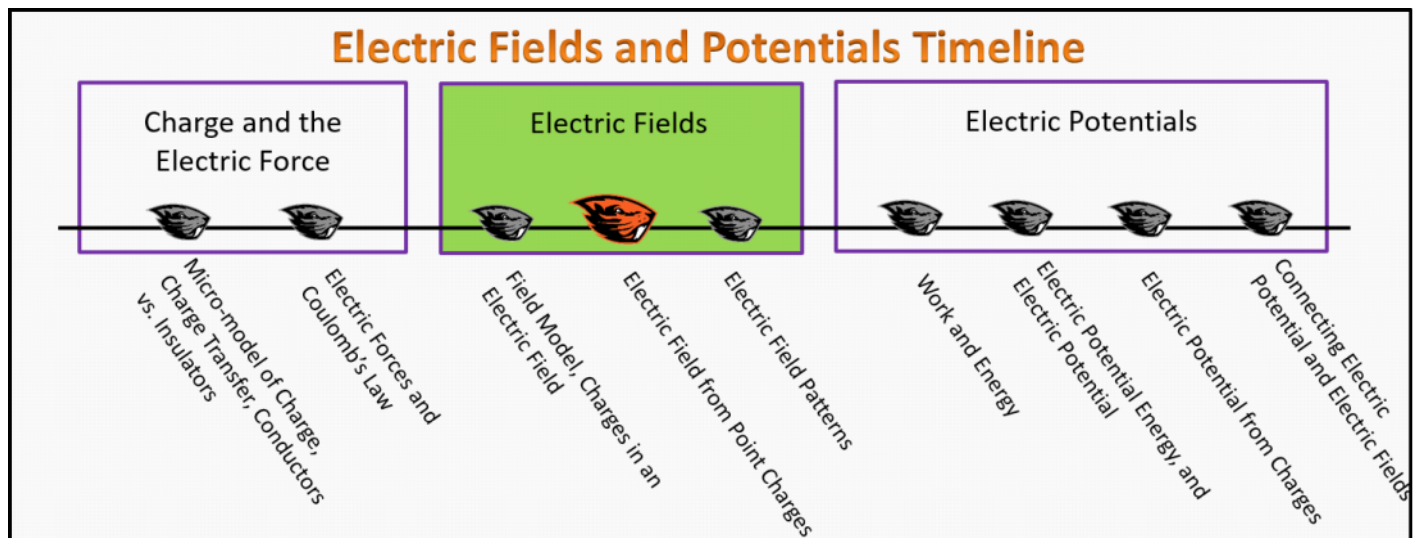


## Electric Fields Foundation Stage (EF.2.L2)

### Lecture 2 Electric Field from Point Charges



### Textbook Chapters (\* Calculus version)

- **BoxSand** :: KC videos ( [Electric Fields](#) )
- **Knight** (College Physics : A strategic approach 3<sup>rd</sup>) :: 20.4 ; 20.5
- **\*Knight** (Physics for Scientists and Engineers 4<sup>th</sup>) :: 22.5
- **Giancoli** (Physics Principles with Applications 7<sup>th</sup>) :: 16-7

### Warm up

#### EF.2.L2-1:

**Description:** Given forces in the mathematical representation, calculate acceleration.

**Learning Objectives:** [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

**Problem Statement:** Three forces act on an object of mass 2 kg:  $\vec{F}^1 = \langle 0,3 \rangle N$  ;  $\vec{F}^2 = \langle 3, -6 \rangle N$  ;  $\vec{F}^3 = \langle -1,2 \rangle N$ . Calculate the acceleration of the object.

## Selected Learning Objectives

1. Coming soon to a lecture template near you.

## Key Terms

- Unit vector
- Charge distribution
- Continuous charge distribution

## Key Equations

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## Key Concepts

- Coming soon to a lecture template near you.

## Questions

# Act I: Electric Field from a Point Charge

**EF.2.L2-2:**

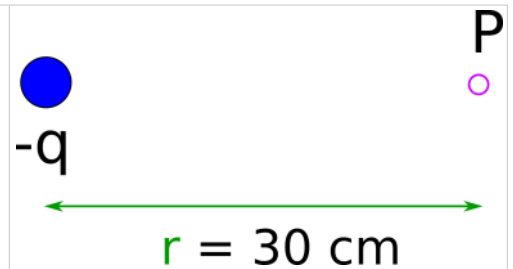
**Description:** Scaffolded question calculating the electric field from a single point charge. (1 minute + 2 minutes + 1 minute + 2 minutes + 1 minute + 4 minutes + 4 minutes + 3 minutes + 3 minutes + 2 minutes)

**Learning Objectives:** [?]

**Problem Statement:** Consider a negative charge  $q_1 = -3 \times 10^{-6} \text{ C}$  that exists in a space far away from other charges. We eventually wish to find the electric field created by  $q_1$  at some point **P** in space which is 30 cm to the right of the point charge.

**(a)** Where would be the wisest place to put an origin?

- (1) Directly on the charge.
- (2) The point **P** in space where we wish to find the field.
- (3) Halfway between the charge and point **P**.
- (4) In a different universe where no charges exist.



**(b)** Using the origin chosen in part (a), what is the position vector to the charge,  $\vec{r}_q$  ?

- (1)  $\langle 0, 0, 0 \rangle \text{ cm}$
- (2)  $\langle -30, 0, 0 \rangle \text{ cm}$
- (3)  $\langle -15, 0, 0 \rangle \text{ cm}$
- (4)  $\langle 0, 30, 0 \rangle \text{ cm}$

**(c)** Using the origin chosen in part (a), what is the position vector to the location of interest at point **P**,  $\vec{r}_p$  ?

- (1)  $\langle 0, 0, 0 \rangle \text{ cm}$
- (2)  $\langle 30, 0, 0 \rangle \text{ cm}$
- (3)  $\langle 15, 0, 0 \rangle \text{ cm}$
- (4)  $\langle 0, 30, 0 \rangle \text{ cm}$

**(d)** What is the change in position from the charge  $q_1$  to the location of interest **P**,  $\Delta\vec{r}_{qp}$  ?

- (1)  $\langle 0, 0, 0 \rangle \text{ cm}$
- (2)  $\langle 30, 0, 0 \rangle \text{ cm}$
- (3)  $\langle 15, 0, 0 \rangle \text{ cm}$
- (4)  $\langle -30, 0, 0 \rangle \text{ cm}$

**(e)** What is the magnitude of the change in position from the charge  $q_1$  to the location of interest **P**,  $|\Delta\vec{r}_{qp}|$  ?

- (1) 0 cm
- (2) 30 cm
- (3) 15 cm
- (4) -30 cm

**(e)** Consider a negative charge  $q_1 = -3 \times 10^{-6} \text{ C}$  that exists in a space far away from other

charges. The electric field from a point particle is given by ,  $\vec{E} = \frac{kq}{|\Delta\vec{r}_{qp}|^2} \Delta\hat{r}_{qp}$  . What is the value of the stuff in front of the unit displacement vector? (  $k \approx 9.00 \times 10^9 \text{ N m}^2/\text{C}^2$  )

- (1) 30 N/C
- (2) - 30 N/C
- (3) 900 N/C
- (4) - 900 N/C
- (5) 300,000 N/C
- (6) -300,000 N/C

(f) Which of the following represents the unit displacement vector ,  $\Delta\hat{r}_{qp}$  ?

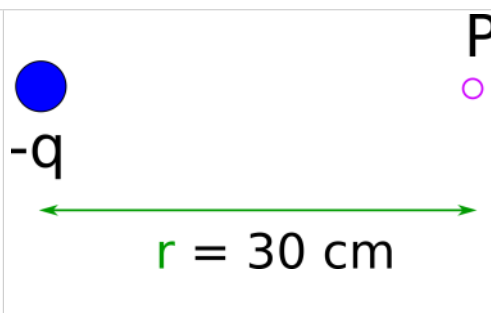
- (1)  $\langle 0, 0, 0 \rangle$
- (2)  $\langle 1, 0, 0 \rangle$
- (3)  $\langle -1, 0, 0 \rangle$
- (4)  $\langle 30, 0, 0 \rangle \text{ cm}$

(g) Consider a negative charge  $q_1 = - 3 \times 10^{-6} \text{ C}$  that exists in a space far away from other charges. Calculate the electric field created by  $q_1$ . at some point **P** in space which is 30 cm to the right of the point charge.

- (1)  $\langle -300,000, 0, 0 \rangle \text{ N/C}$
- (2)  $\langle 300,000, 0, 0 \rangle \text{ N/C}$
- (3)  $\langle -30, 0, 0 \rangle \text{ N/C}$
- (4)  $\langle 30, 0, 0 \rangle \text{ N/C}$

(h) A positive charge  $q_o = 2 \times 10^{-6} \text{ C}$  is placed at point **P** which is 30 cm to the right of a point charge of  $q_1 = -3 \times 10^{-6} \text{ C}$ . What is the electric force on  $q_o$  from the field created by  $q_1$ ?

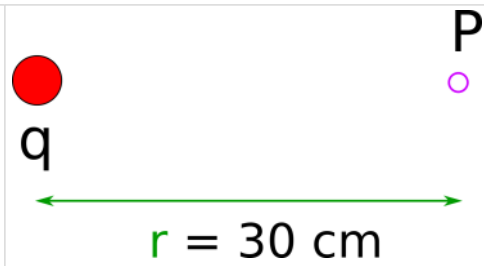
- (1)  $\langle -6, 0, 0 \rangle \text{ N}$
- (2)  $\langle 6, 0, 0 \rangle \text{ N}$
- (3)  $\langle -0.6, 0, 0 \rangle \text{ N}$
- (4)  $\langle 0.6, 0, 0 \rangle \text{ N}$



(i) In part (g) we found the electric field at a location 30 cm to the right of a charge  $q_1 = - 3 \times 10^{-6} \text{ C}$ . Which of the following would be the electric field at the same location if the charge

$q_1$  were positive instead of negative?

- (1)  $\langle -300,000, 0, 0 \rangle$  N/C
- (2)  $\langle 300,000, 0, 0 \rangle$  N/C
- (3)  $\langle -30, 0, 0 \rangle$  N/C
- (4)  $\langle 30, 0, 0 \rangle$  N/C



## Act II: Electric Field from Multiple Point Charges

### EF.2.L2-3:

**Description:** Calculate electric field from 4 point charges with symmetry. (4 minutes)

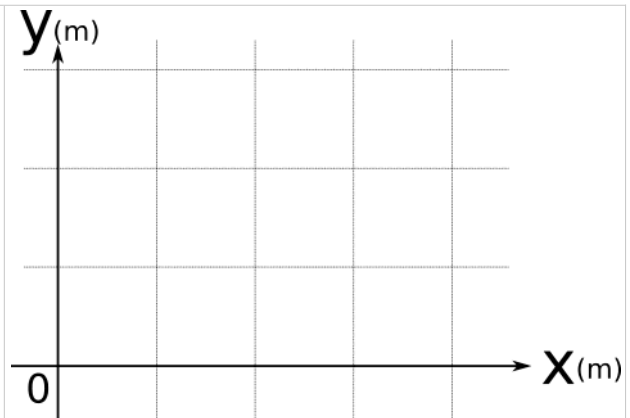
**Learning Objectives:** [?]

**Problem Statement:** Four charges, all of which are  $q = -2e$  are placed at the following coordinates:

$\langle 3, 2, 0 \rangle$ m	$\langle 1, 2, 0 \rangle$ m	$\langle 1, 0, 0 \rangle$ m	$\langle 3, 0, 0 \rangle$ m
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What is the electric field at the location  $\langle 2, 1, 0 \rangle$  m ?

- (1)  $\langle 0, 0, 0 \rangle$  N/C
- (2)  $\langle 1/\sqrt{2}, 1/\sqrt{2}, 0 \rangle$  N/C
- (3)  $\langle -1/\sqrt{2}, -1/\sqrt{2}, 0, 0 \rangle$  N/C
- (4)  $\langle -1/\sqrt{2}, 1/\sqrt{2}, 0, 0 \rangle$  N/C
- (5)  $\langle 1/\sqrt{2}, -1/\sqrt{2}, 0, 0 \rangle$  N/C



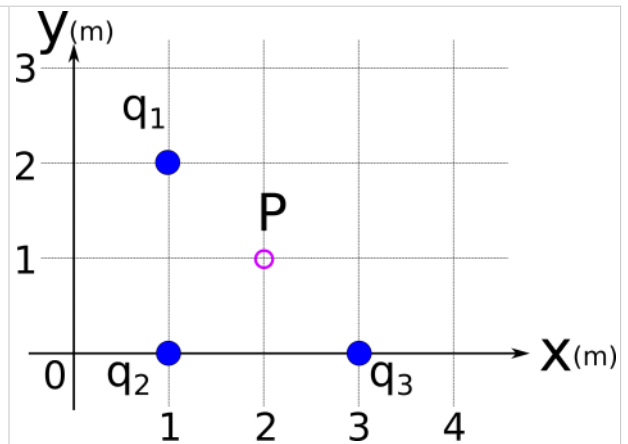
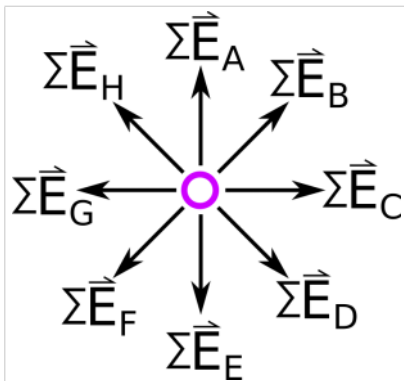
**EF.2.L2-4:**

**Description:** Scaffolded question calculating the electric field from three point charges with symmetry. (4 minutes + 1 minute + 2 minutes + 1 minute + 2 minutes + 1 minute + 4 minutes + 4 minutes + 3 minutes + 3 minutes + 2 minutes)

**Learning Objectives:** [?]

**Problem Statement:** Consider the charge distribution with 3 point charges shown in the figure below. All charges have charge  $q = -e$ .

**(a)** Which of the following vectors best represents the net electric field at location P?



**(b)** Using the origin given in the figure, what is the position vector to the charge 2,  $\vec{r}_2$  ?

- (1)  $\langle 0, 0, 0 \rangle$  m
- (2)  $\langle 1, 0, 0 \rangle$  m
- (3)  $\langle -1, 0, 0 \rangle$  m
- (4)  $\langle 0, 1, 0 \rangle$  m

**(c)** Using the origin given in the figure, what is the position vector to the location of interest at point P,  $\vec{r}_p$  ?

- (1)  $\langle 2, 0, 0 \rangle$  m
- (2)  $\langle 2, 1, 0 \rangle$  m
- (3)  $\langle 2, 2, 0 \rangle$  m
- (4)  $\langle 1, 1, 0 \rangle$  m

**(d)** What is the change in position from

**(e)** What is the magnitude of the change in

the charge  $q_2$  to the location of interest  $P$ ,  $\Delta\vec{r}_{2p}$  ?

- (1)  $\langle 1, 1, 0 \rangle$  m
- (2)  $\langle -1, 1, 0 \rangle$  m
- (3)  $\langle -1, -1, 0 \rangle$  m
- (4)  $\langle 0, 1, 0 \rangle$  m

position from the charge  $q_2$  to the location of interest  $P$ ,  $|\Delta\vec{r}_{2p}|$  ?

- (1) 1 m
- (2) 2 m
- (3)  $\sqrt{2}$  m
- (4) -2 m

(e) Consider the charge distribution with 3 point charges shown in the figure below. All charges have charge  $q = -e$ . The electric field from a point particle is given by,  $\vec{E} = \frac{kq}{|\Delta\vec{r}_{qp}|^2} \Delta\hat{r}_{qp}$ . What is the value of the stuff in front of the unit displacement vector for the electric field contribution from  $q_2$ ?

- (1)  $\frac{ke}{2} \frac{1}{m}$
- (2)  $\frac{ke^2}{2} \frac{1}{m}$
- (3)  $\frac{-ke}{2} \frac{1}{m}$
- (4)  $\frac{-ke}{\sqrt{2}} \frac{1}{m}$
- (5)  $\frac{ke}{\sqrt{2}} \frac{1}{m}$

(f) Which of the following represents the unit displacement vector,  $\Delta\hat{r}_{2p}$  ?

- (1)  $\langle 1/\sqrt{2}, 1/\sqrt{2}, 1/\sqrt{2} \rangle$
- (2)  $\langle 1, 0, 0 \rangle$
- (3)  $\langle 1, 1, 0 \rangle$
- (4)  $\langle 1/\sqrt{2}, 1/\sqrt{2}, 0 \rangle$
- (5)  $\langle -1/\sqrt{2}, -1/\sqrt{2}, 0 \rangle$

**(g)** Consider the charge distribution with 3 point charges shown in the figure below. All charges have charge  $q = -e$ . Calculate the net electric field at the location of interest **P**.

(1)  $\frac{ke}{2} \frac{1}{m} < \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}} > \text{N/C}$

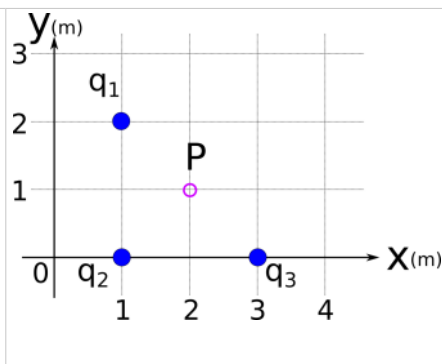
(2)  $-\frac{ke}{2} \frac{1}{m} < \frac{1}{2}, \frac{1}{2}, 0 > \text{N/C}$

(3)  $\frac{ke}{2} \frac{1}{m} < \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0 > \text{N/C}$

(4)  $-\frac{ke}{2} \frac{1}{m} < -\frac{1}{\sqrt{2}}, -\frac{1}{\sqrt{2}}, 0 > \text{N/C}$

**(h)** A positive charge  $q_0 = 2 \times 10^6 \text{ C}$  is placed at point **P**. What is the electric force on  $q_0$  from the field created by the 3 point charge distribution? ( $k \approx 9.00 \times 10^9 \text{ N m}^2/\text{C}^2$  ;  $e \approx 1.60 \times 10^{-19} \text{ C}$ )

- (1)  $< -1.02, 0, 0 > \mu\text{N}$   
 (2)  $< 1.02, 0, 0 > \mu\text{N}$   
 (3)  $< -1.44, 0, 0 > \mu\text{N}$   
 (4)  $< 1.44, 0, 0 > \mu\text{N}$



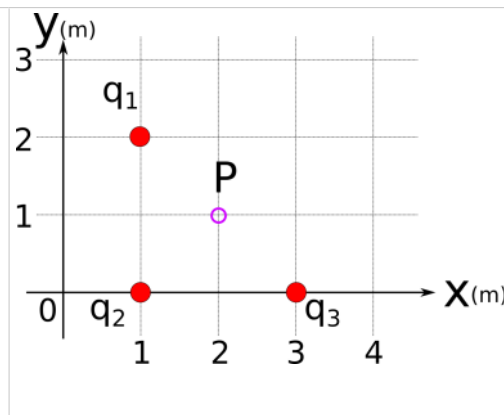
**(i)** In part **(g)** we found the electric field at point **P**. Which of the following would be the electric field at the same location if all of the charges in the distribution were positive instead of negative?

(1)  $\frac{ke}{2} \frac{1}{m} < \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}} > \text{N/C}$

(2)  $-\frac{ke}{2} \frac{1}{m} < \frac{1}{2}, \frac{1}{2}, 0 > \text{N/C}$

(3)  $\frac{ke}{2} \frac{1}{m} < \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0 > \text{N/C}$

(4)  $-\frac{ke}{2} \frac{1}{m} < -\frac{1}{\sqrt{2}}, -\frac{1}{\sqrt{2}}, 0 > \text{N/C}$



## Act III: Approximating Electric Field from Continuous Charge Distributions

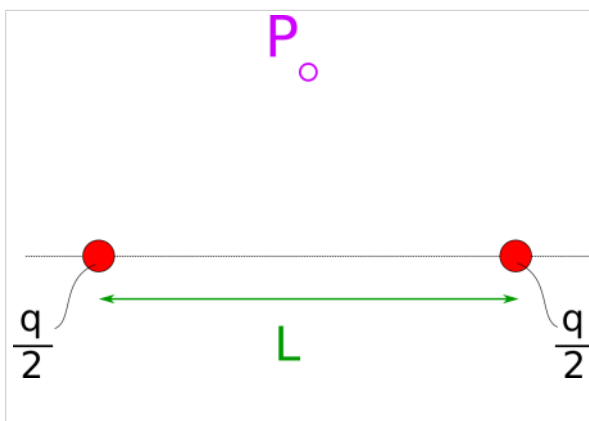
### EF.2.L2-5:

**Description:** Estimate the direction of the electric field from given charge distributions. (3 minutes + 3 minutes + 3 minutes)

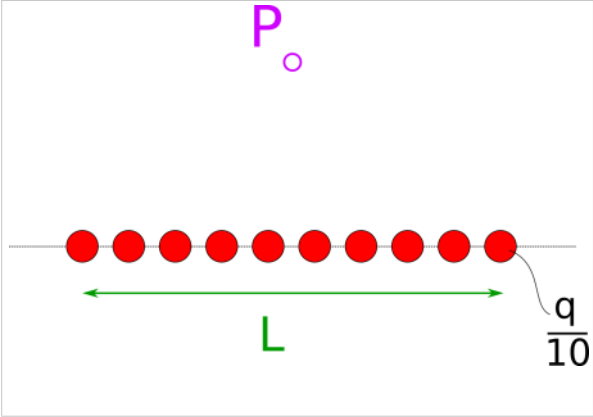
### Learning Objectives: [?]

**Problem Statement:** Sketch the electric field due to the following charge distributions at the location of interest labeled **P**.

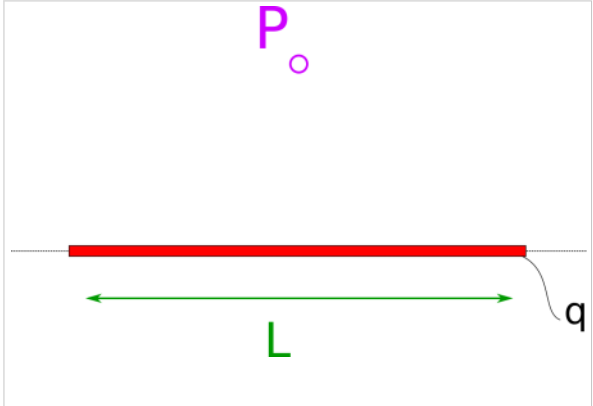
(a) Two point charges are placed along the x-axis as shown in the figure below. Each charge has a charge  $q_1 = q_2 = q/2$ .



(b) Ten point charges are placed along the x-axis as shown in the figure below. Each charge has a charge  $q_1 = q_2 = \dots = q/10$ .



(c) A line of continuous charge distribution (i.e. an infinite number of point charges) has its charge uniformly distributed and lies along the x-axis as shown in the figure below. The net charge on the continuous charged line is  $q$ .



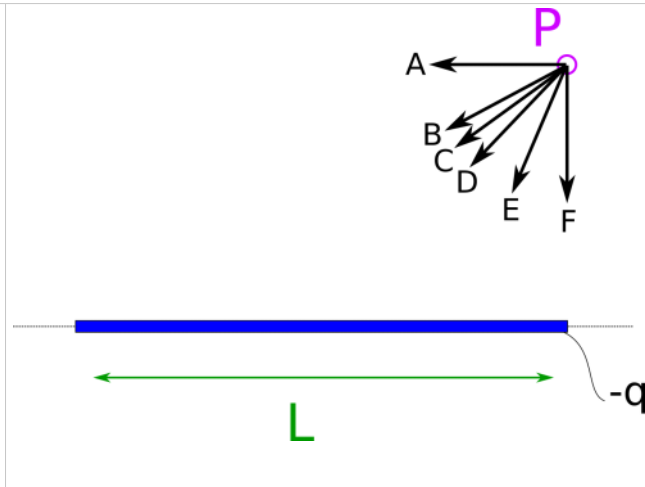
**EF.2.L2-6:**

**Description:** Estimate the direction of the electric field from given charge distributions. (4 minutes)

**Learning Objectives:** [?]

**Problem Statement:** Consider a short rod carrying a uniformly distributed negative charge. Which vector most closely represents the direction of the electric field at point P?

- (1) A
- (2) B
- (3) C
- (4) D
- (5) E
- (6) F
- (7) The answer depends on the sign of the charge of the test particle.



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## Conceptual questions for discussion

1. Coming soon to a lecture template near you.
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## Hints

**EF.2.L2-1:** No hints.

**EF.2.L2-2:** No hints.

**EF.2.L2-3:** No hints.

**EF.2.L2-4:** No hints.

**EF.2.L2-5:** No hints.

**EF.2.L2-6:** No hints.