PC212 Tutorial Problem Wilfrid Laurier University

Terry Sturtevant

Wilfrid Laurier University

April 29, 2011

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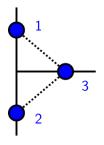
Definition Before Math Calculations Check

Definition

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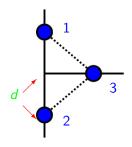
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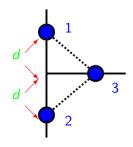
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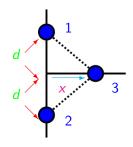
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Definition Before Math Calculations Check

• $q_1 = q_2 = +3.20 \times 10^{-19} C$

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Definition Before Math Calculations Check

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Definition Before Math Calculations Check

•
$$q_1 = q_2 = +3.20 \times 10^{-19} C$$

- $q_3 = +6.40 \times 10^{-19} C$
- d = 17.0 cm

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Definition Before Math Calculations Check

- $q_1 = q_2 = +3.20 \times 10^{-19} C$
- $q_3 = +6.40 \times 10^{-19} C$
- d = 17.0 cm
- x goes from $0 \rightarrow 5.0m$

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We want to know:

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- $q_1 = q_2 = +3.20 \times 10^{-19} C$
- $q_3 = +6.40 \times 10^{-19} C$
- *d* = 17.0*cm*
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We want to know: (a) x_0 , where $\left|\vec{F}\right|_{3,net}$ is a minimum

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We want to know: (a) x_0 , where $\left| \vec{F} \right|_{3,net}$ is a minimum (b) x_1 , where $\left| \vec{F} \right|_{3,net}$ is a maximum

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- $q_3 = +6.40 \times 10^{-19} C$
- *d* = 17.0*cm*
- x goes from $0 \rightarrow 5.0m$

We want to know: (a) x_0 , where $\left| \vec{F} \right|_{3,net}$ is a minimum (b) x_1 , where $\left| \vec{F} \right|_{3,net}$ is a maximum (c) What is $\left| \vec{F} \right|_{3,net} (x_0)$?

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Definition Before Math Calculations Check

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We want to know:
(a)
$$x_0$$
, where $\left| \vec{F} \right|_{3,net}$ is a minimum
(b) x_1 , where $\left| \vec{F} \right|_{3,net}$ is a maximum
(c) What is $\left| \vec{F} \right|_{3,net} (x_0)$?
(d) What is $\left| \vec{F} \right|_{3,net} (x_1)$?

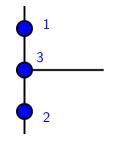
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Before Math

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Before Math



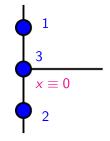
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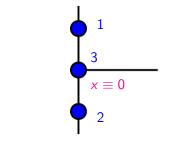
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By symmetry,
$$\left| \vec{F} \right|_{3,net} (x_0) \equiv 0$$

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Definition Before Math Calculations Check

Before Math

$$\begin{array}{c}
1 \\
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x \equiv 0 \\
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\end{array}$$

By symmetry,
$$\left| \vec{F} \right|_{3,net} (x_0) \equiv 0$$

This answers (a) and (c).

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By symmetry we also know that the vertical forces cancel anywhere along the x axis;

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Definition Before Math Calculations Check

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$$\left|\vec{F}\right|_{3,net} \equiv |F_x|_{3,net}$$

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Definition Before Math Calculations Check

By symmetry we also know that the vertical forces cancel anywhere along the x axis; i.e.

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Also, the contributions from q_1 and q_2 are equal so that

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Definition Before Math Calculations Check

By symmetry we also know that the vertical forces cancel anywhere along the x axis; i.e.

$$\left|\vec{F}\right|_{3,net} \equiv |F_x|_{3,net}$$

Also, the contributions from q_1 and q_2 are equal so that

$$|F_x|_{3,net} = |F_{x31} + F_{x32}| = 2|F_{x31}|$$

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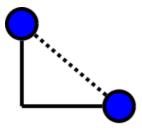
Definition Before Math Calculations Check

Calculations

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Definition Before Math Calculations Check

Calculations



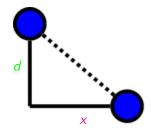
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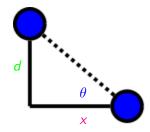
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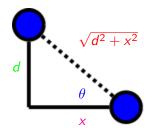
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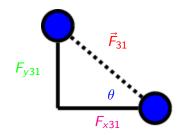
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Definition Before Math Calculations Check

$$F_{x31} = \vec{F}_{31} \cos \theta$$

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Definition Before Math Calculations Check

$$F_{x31} = \vec{F}_{31} \cos \theta$$

$$F_{x31} = \vec{F}_{31} \frac{x}{\sqrt{d^2 + x^2}}$$

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Chapter	21 -	Problem	23.	9th	edition	

Definition Before Math Calculations Check

$$F_{x31} = \vec{F}_{31} \cos \theta$$
$$F_{x31} = \vec{F}_{31} \frac{x}{\sqrt{d^2 + x^2}}$$
$$\vec{F}_{31} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_3}{(d^2 + x^2)}$$

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Definition Before Math Calculations Check

$$F_{x31} = \vec{F}_{31} \cos \theta$$

$$F_{x31} = \vec{F}_{31} \frac{x}{\sqrt{d^2 + x^2}}$$

$$\vec{F}_{31} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_3}{(d^2 + x^2)}$$

$$\therefore F_{x31} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_3}{(d^2 + x^2)} \frac{x}{\sqrt{d^2 + x^2}} = \frac{q_1 q_3}{4\pi\epsilon_0} \frac{x}{(d^2 + x^2)^{3/2}}$$

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Definition Before Math Calculations Check

Force will be a maximum when

 $\frac{\mathrm{d}\boldsymbol{F}_{\boldsymbol{x}\boldsymbol{3}\boldsymbol{1}}}{\mathrm{d}\boldsymbol{x}}\equiv\boldsymbol{0}$

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Definition Before Math Calculations Check

Force will be a maximum when

$$\frac{\mathrm{d}F_{x31}}{\mathrm{d}x} \equiv 0$$
$$\frac{\mathrm{d}}{\mathrm{d}x} \left(\frac{q_1 q_3}{4\pi\epsilon_0} \frac{x}{\left(d^2 + x^2\right)^{3/2}} \right) \equiv 0$$

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which reduces to

$$\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{x}{\left(d^2+x^2\right)^{3/2}}\right)\equiv 0$$

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Definition Before Math Calculations Check

Force will be a maximum when

$$\frac{\mathrm{d}F_{x31}}{\mathrm{d}x} \equiv 0$$
$$\frac{\mathrm{d}}{\mathrm{d}x} \left(\frac{q_1 q_3}{4\pi\epsilon_0} \frac{x}{\left(d^2 + x^2\right)^{3/2}} \right) \equiv 0$$

which reduces to

$$\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{x}{\left(d^2+x^2\right)^{3/2}}\right)\equiv 0$$

since none of the other terms are zero.

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Definition Before Math Calculations Check

By the quotient rule

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Definition Before Math Calculations Check

By the quotient rule

$$\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{x}{\left(d^2+x^2\right)^{3/2}}\right) = \frac{\left(1\right)\left(d^2+x^2\right)^{3/2}-\left(x\right)\frac{\mathrm{d}}{\mathrm{d}x}\left(d^2+x^2\right)^{3/2}}{\left(\left(d^2+x^2\right)^{3/2}\right)^2} = 0$$

Definition Before Math Calculations Check

By the quotient rule

$$\frac{\mathrm{d}}{\mathrm{d}x} \left(\frac{x}{\left(d^2 + x^2\right)^{3/2}} \right) = \frac{\left(1\right) \left(d^2 + x^2\right)^{3/2} - \left(x\right) \frac{\mathrm{d}}{\mathrm{d}x} \left(d^2 + x^2\right)^{3/2}}{\left(\left(d^2 + x^2\right)^{3/2}\right)^2} = 0$$
$$\therefore (1) \left(d^2 + x^2\right)^{3/2} - (x) \frac{\mathrm{d}}{\mathrm{d}x} \left(d^2 + x^2\right)^{3/2} = 0$$

Definition Before Math Calculations Check

By the quotient rule

$$\frac{\mathrm{d}}{\mathrm{d}x} \left(\frac{x}{(d^2 + x^2)^{3/2}} \right) = \frac{(1) \left(d^2 + x^2 \right)^{3/2} - (x) \frac{\mathrm{d}}{\mathrm{d}x} \left(d^2 + x^2 \right)^{3/2}}{\left((d^2 + x^2)^{3/2} \right)^2} = 0$$
$$\therefore (1) \left(d^2 + x^2 \right)^{3/2} - (x) \frac{\mathrm{d}}{\mathrm{d}x} \left(d^2 + x^2 \right)^{3/2} = 0$$

since

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$$\frac{\mathrm{d}}{\mathrm{d}x} \left(\frac{x}{\left(d^2 + x^2\right)^{3/2}} \right) = \frac{\left(1\right) \left(d^2 + x^2\right)^{3/2} - \left(x\right) \frac{\mathrm{d}}{\mathrm{d}x} \left(d^2 + x^2\right)^{3/2}}{\left(\left(d^2 + x^2\right)^{3/2}\right)^2} = 0$$
$$\therefore (1) \left(d^2 + x^2\right)^{3/2} - (x) \frac{\mathrm{d}}{\mathrm{d}x} \left(d^2 + x^2\right)^{3/2} = 0$$

since

$$\left(\left(d^2+x^2\right)^{3/2}\right)^2\neq 0$$

Definition Before Math Calculations Check

$$(1) \left(d^2 + x^2\right)^{3/2} - (x) \frac{\mathrm{d}}{\mathrm{d}x} \left(d^2 + x^2\right)^{3/2}$$

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Definition Before Math Calculations Check

$$(1) (d^{2} + x^{2})^{3/2} - (x) \frac{d}{dx} (d^{2} + x^{2})^{3/2}$$
$$= (1) (d^{2} + x^{2})^{3/2} - (x) \frac{3}{2} (d^{2} + x^{2})^{1/2} (2x)$$

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Chapter 21 -	Problem 23,	9th edition	

Definition Before Math Calculations Check

$$(1) (d^{2} + x^{2})^{3/2} - (x) \frac{d}{dx} (d^{2} + x^{2})^{3/2}$$
$$= (1) (d^{2} + x^{2})^{3/2} - (x) \frac{3}{2} (d^{2} + x^{2})^{1/2} (2x)$$
$$= (d^{2} + x^{2})^{3/2} - (2x^{2}) \frac{3}{2} (d^{2} + x^{2})^{1/2}$$

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Chapter 21 -	Problem 23,	9th edition	

Definition Before Math Calculations Check

$$(1) (d^{2} + x^{2})^{3/2} - (x) \frac{d}{dx} (d^{2} + x^{2})^{3/2}$$
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$$= (d^{2} + x^{2})^{3/2} - (2x^{2}) \frac{3}{2} (d^{2} + x^{2})^{1/2}$$
$$= (d^{2} + x^{2}) - 3x^{2} = 0$$

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Chapter 21 - Problem 23, 9th edition	Before Math
Chapter 21 - 1 Toblem 25, 5th edition	Calculations

(1) $(d^2 + x^2)^{3/2} - (x) \frac{d}{dx} (d^2 + x^2)^{3/2}$ $= (1) \left(d^2 + x^2 \right)^{3/2} - (x) \frac{3}{2} \left(d^2 + x^2 \right)^{1/2} (2x)$ $= \left(d^2 + x^2\right)^{3/2} - \left(2x^2\right)\frac{3}{2}\left(d^2 + x^2\right)^{1/2}$ $= (d^2 + x^2) - 3x^2 = 0$ after factoring out $(d^2 + x^2)^{1/2}$

Definition Before Math Calculations Check

 $\left(d^2 + x^2\right) - 3x^2$

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Definition Before Math Calculations Check

 $\left(d^2 + x^2\right) - 3x^2$

$$= d^2 - 2x^2$$

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Definition Before Math Calculations Check

$$\left(d^2 + x^2\right) - 3x^2$$

$$= d^2 - 2x^2$$

= 0

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Definition Before Math Calculations Check

$$\left(d^2 + x^2\right) - 3x^2$$

$$= d^2 - 2x^2$$

= 0

$$\rightarrow x^2 = \frac{d^2}{2}$$

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Definition Before Math Calculations Check

$$\left(d^2 + x^2\right) - 3x^2$$

$$= d^2 - 2x^2$$

= 0

$$x^2 = \frac{d^2}{2}$$
$$x = \pm \frac{d}{\sqrt{2}}$$

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Definition Before Math Calculations Check

From the definition, we're only interested in the solution when x goes from $0 \rightarrow 5.0m$, so reject

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d = 17.0 cm

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$$x = \frac{17.0}{\sqrt{2}} \approx 12.0 cm$$

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Definition Before Math Calculations Check

$x \approx 12.0 cm$

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Definition Before Math Calculations Check

$x \approx 12.0 cm$

so

 $|F_x|_{3,net} = 2 |F_{x31}|$

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Definition Before Math Calculations Check

$x \approx 12.0$ cm

so

 $|F_x|_{3,net} = 2 |F_{x31}|$

$$=2\frac{q_1q_3}{4\pi\epsilon_0}\frac{x}{(d^2+x^2)^{3/2}}$$

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Definition Before Math Calculations Check

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(You can do the calculations.)

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Definition Before Math Calculations Check

$x \approx 12.0 cm$

so

 $|F_x|_{3,net} = 2|F_{x31}|$

$$=2\frac{q_1q_3}{4\pi\epsilon_0}\frac{x}{\left(d^2+x^2\right)^{3/2}}$$

(You can do the calculations.) This answers (b) and (d).

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Definition Before Math Calculations **Check**

Check

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Definition Before Math Calculations **Check**

Check

We should verify that the force is indeed a maximum,

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Definition Before Math Calculations **Check**

Check

We should verify that the force is indeed a *maximum*, (rather than a *minimum*),

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Definition Before Math Calculations **Check**

Check

We should verify that the force is indeed a maximum, (rather than a minimum), at $x \approx 12.0$ cm.

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Definition Before Math Calculations **Check**

Check

We should verify that the force is indeed a maximum, (rather than a minimum), at $x \approx 12.0$ cm.

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Definition Before Math Calculations **Check**

Check

We should verify that the force is indeed a maximum, (rather than a minimum), at $x \approx 12.0$ cm.

Since

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we've shown that F \equiv 0 at x = 0,
```

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Check

We should verify that the force is indeed a maximum, (rather than a minimum), at $x \approx 12.0$ cm.

Since

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Check

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We should verify that the force is indeed a maximum,
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we've shown that F \equiv 0 at x = 0,
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Definition Before Math Calculations **Check**

Check

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We should verify that the force is indeed a maximum,
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```

Since

```
we've shown that F \equiv 0 at x = 0,
we know that F \rightarrow 0 as x \rightarrow \infty,
and by the equation, in between F is always positive,
then F must be a maximum at that point.
```

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