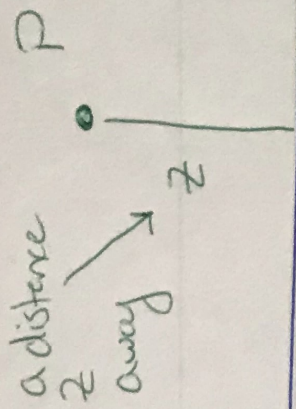




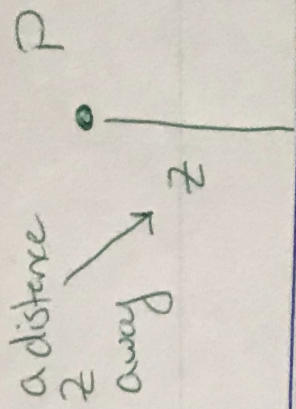
A long thin wire with charge density  $\lambda$



What is  $\vec{E}$  at P + P

*[Faint, mostly illegible text from the reverse side of the page, including phrases like 'How do you find the electric field...']*

A long thin wire with charge density  $\lambda$



What is  $\vec{E}$  at P + P

Handwritten notes and calculations on lined paper, including a table with columns labeled 1 through 5 and rows of numbers.

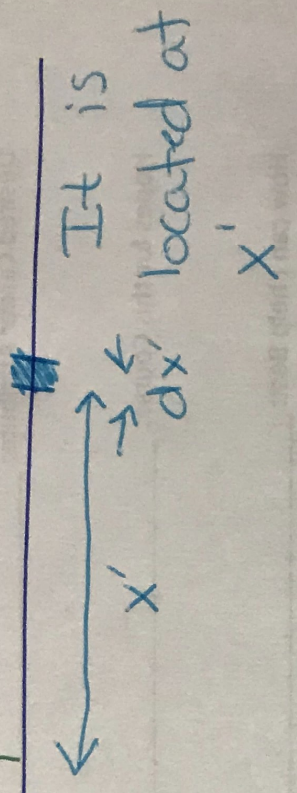
|   |   |   |   |   |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |

A long thin wire with charge density  $\lambda$

a distance  $z$  away

Choose a bit of charge  $dq$

what is  $\vec{E}$  at  $P$



A long thin wire with charge density  $\lambda$

What is  $\vec{E}$  at P + P

Choose a bit of charge  $dq$

It is located at  $x'$

Script R

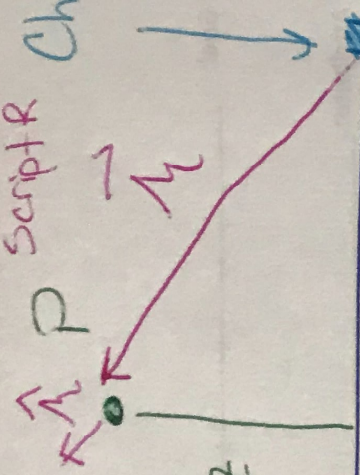
P

a distance  $z$  away

$z$

$x'$

$dx'$



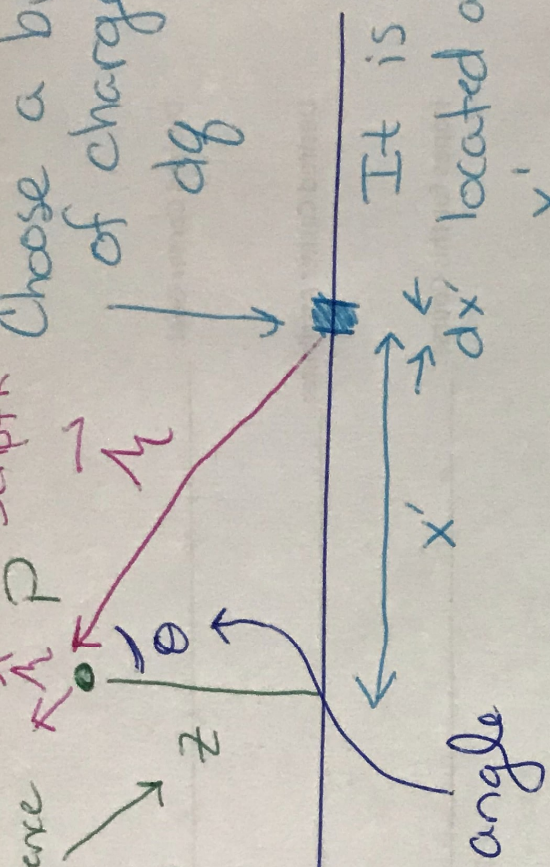
A long thin wire with charge density  $\lambda$

a distance  $z$  away

Choose a bit of charge  $dq$

what is  $\vec{E}$  at P + P

It is located at  $x'$



|   |   |   |   |   |   |   |   |   |    |
|---|---|---|---|---|---|---|---|---|----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

How do you find the electric field at point P?

you find the electric field at point P

you find the electric field at point P

A long thin wire with charge density  $\lambda$

Choose a bit of charge  $dq$

Script R

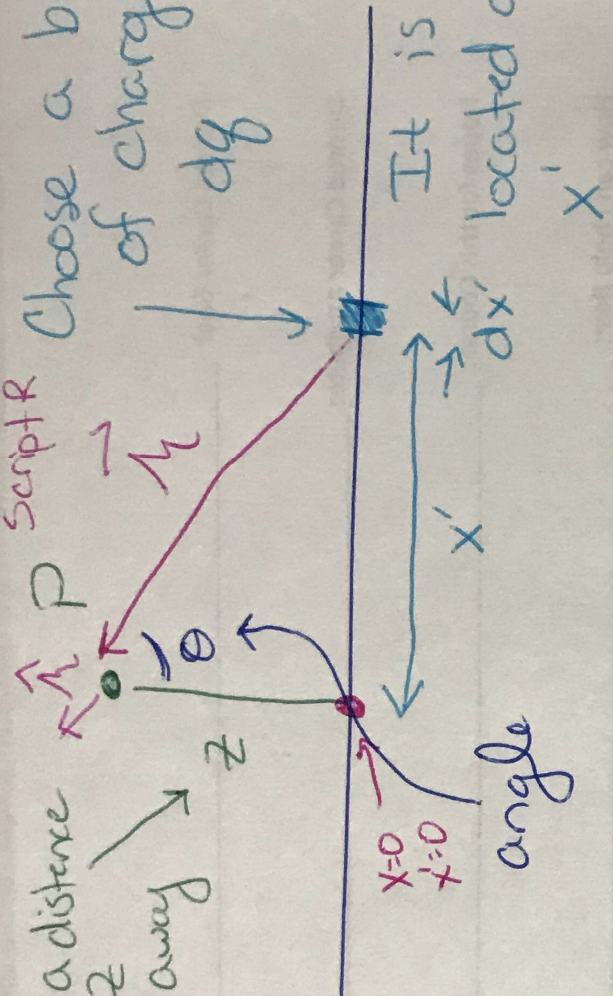
a distance  $z$  away

what is  $\vec{E}$  at P + P

$x=0$   
 $y=0$

angle

It is located at  $x'$

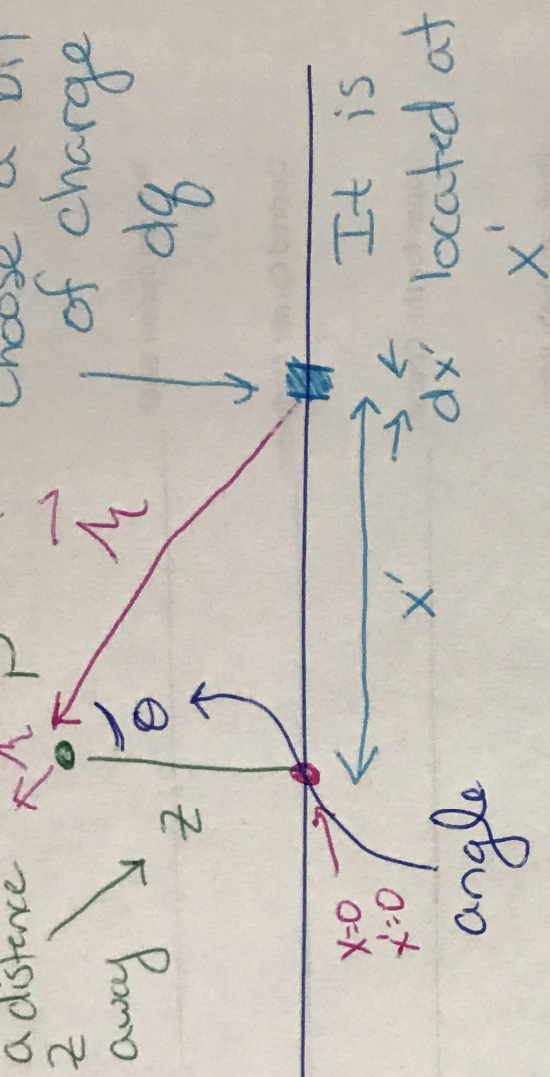


$$|r| = \sqrt{x'^2 + z^2}$$

$$\vec{r} = (x-x')\hat{i} + (y-y')\hat{j} + (z-z')\hat{k}$$

$$\vec{r} = -x'\hat{i} + z\hat{k}$$

A long thin wire with charge density  $\lambda$



what is  $\vec{E}$  at P + P

$$|\vec{r}| = \sqrt{x'^2 + z^2}$$

$$\vec{r} = (x-x')\hat{i} + (y-y')\hat{j} + (z-z')\hat{k}$$

$$\vec{r} = -x'\hat{i} + z\hat{k}$$

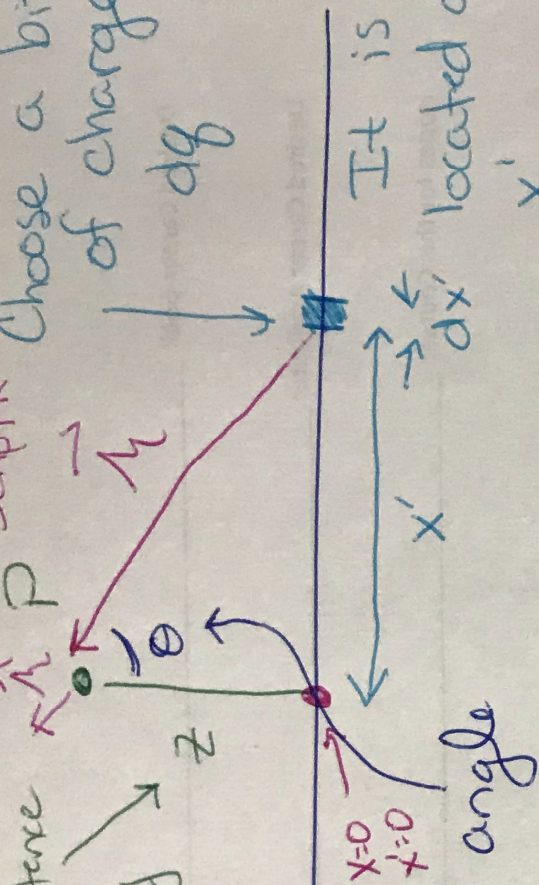
$$\hat{r} = \frac{\vec{r}}{r} = -\frac{x'\hat{i} + z\hat{k}}{\sqrt{x'^2 + z^2}}$$

$$\hat{r} = -\frac{x'}{\sqrt{x'^2 + z^2}}\hat{i} + \frac{z}{\sqrt{x'^2 + z^2}}\hat{k}$$

A long thin wire with charge density  $\lambda$

a distance  $z$  away

Choose a bit of charge  $dq$



what is  $\vec{E}$  at P + P

$$|\vec{r}| = \sqrt{x'^2 + z^2}$$

$$\vec{r} = (x-x')\hat{i} + (y-y')\hat{j} + (z-z')\hat{k}$$

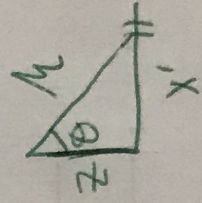
$$\vec{r} = -x'\hat{i} + z\hat{k}$$

$$\hat{r} = \frac{\vec{r}}{r} = -\frac{x'\hat{i} + z\hat{k}}{\sqrt{x'^2 + z^2}}$$

$$\hat{r} = -\frac{x'}{\sqrt{x'^2 + z^2}}\hat{i} + \frac{z}{\sqrt{x'^2 + z^2}}\hat{k}$$

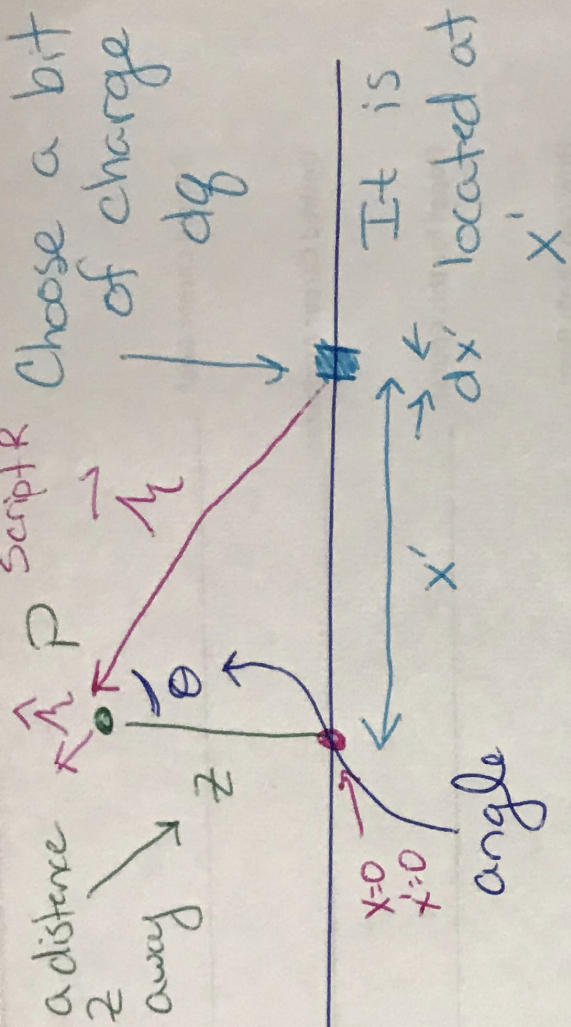
trick

$$\hat{r} = -\sin\theta\hat{i} + \cos\theta\hat{k}$$



A long thin wire with charge density  $\lambda$

what is  $\vec{E}$  at P + P



$$|r| = \sqrt{x'^2 + z^2}$$

$$\vec{r} = (x-x')\hat{i} + (y-y')\hat{j} + (z-z')\hat{k}$$

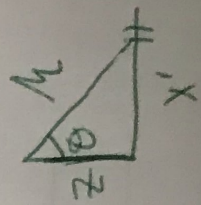
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trick

$$\hat{r} = -\sin\theta\hat{i} + \cos\theta\hat{k}$$



$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{dq}{r^2} \hat{r} = \frac{1}{4\pi\epsilon_0} \int \frac{\lambda dx'}{r^2} \hat{r}$$

$$\frac{1}{\mu^2} \rightarrow \frac{\cos^2 \theta}{z^2}$$

$$\frac{z}{\mu} \rightarrow \cos \theta$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\gamma \cdot \cos^2 \theta}{z^2} \hat{n} dx'$$

$$\frac{1}{r^2} \rightarrow \frac{\cos^2 \theta}{z^2}$$

$$\frac{z}{r} \rightarrow \cos \theta$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\hat{r} \cdot \cos^2 \theta}{z^2} \cdot \hat{n} \, dx'$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\hat{r}}{z^2} \cos^2 \theta [-\sin \theta \hat{i} + \cos \theta \hat{k}] \, dx'$$

$$\frac{1}{\mu^2} \rightarrow \frac{\cos^2 \theta}{z^2}$$

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$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\hat{r} \cdot \cos^2 \theta}{z^2} \cdot \hat{\mu} \, dx'$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\hat{r}}{z^2} \cos^2 \theta [-\sin \theta \hat{i} + \cos \theta \hat{k}] \, dx'$$

NEED TRICK

$$\frac{x'}{z} = \tan \theta$$

$$x' = z \tan \theta$$

$$dx' = z \frac{1}{\cos^2 \theta} d\theta$$

$$\frac{1}{\mu^2} \rightarrow \frac{\cos^2 \theta}{z^2}$$

$$\frac{z}{\mu} \rightarrow \cos \theta$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\lambda \cdot \cos^2 \theta}{z^2} \cdot \hat{\mu} \, dx'$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{\lambda}{z^2} \int \cos^2 \theta [-\sin \theta \hat{i} + \cos \theta \hat{k}] \, dx'$$

NEED trick

$$\frac{x'}{z} = \tan \theta$$

$$x' = z \tan \theta$$

$$dx' = z \frac{1}{\cos^2 \theta} d\theta$$

$$\vec{E} = \frac{\lambda}{4\pi\epsilon_0 z^2} \int \cos^2 \theta [-\sin \theta \hat{i} + \cos \theta \hat{k}] \frac{z \, d\theta}{\cos^2 \theta}$$

$$\frac{1}{\mu^2} \rightarrow \frac{\cos^2 \theta}{z^2}$$

$$\frac{z}{\mu} \rightarrow \cos \theta$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\gamma \cdot \cos^2 \theta}{z^2} \cdot \hat{n} \, dx'$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{\gamma}{z^2} \int \cos^2 \theta [-\sin \theta \hat{i} + \cos \theta \hat{k}] \, dx'$$

NEED trick

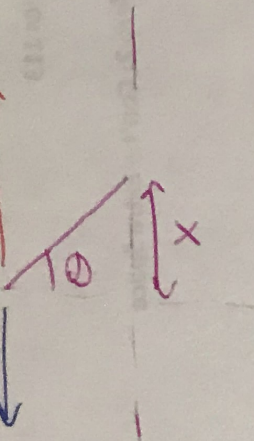
$$\frac{x'}{z} = \tan \theta$$

$$x' = z \tan \theta$$

$$dx' = z \frac{1}{\cos^2 \theta} d\theta$$

$$\vec{E} = \frac{\gamma}{4\pi\epsilon_0 z^2} \int \cos^2 \theta [-\sin \theta \hat{i} + \cos \theta \hat{k}] \frac{z \, d\theta}{\cos^2 \theta}$$

$$\vec{E} = \frac{\gamma}{4\pi\epsilon_0 z} \left\{ -\int \sin \theta \, d\theta \hat{i} + \int \cos \theta \, d\theta \hat{k} \right.$$



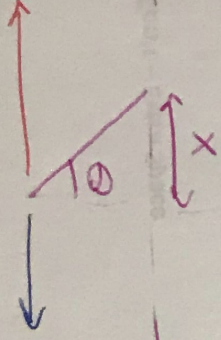
$$x \rightarrow -\infty$$

$$\theta \rightarrow -\pi/2$$

$$x \rightarrow +\infty$$

$$\theta \rightarrow +\pi/2$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0 z} \left\{ - \int_{-\pi/2}^{\pi/2} \sin \theta \, d\theta \hat{i} + \int_{-\pi/2}^{\pi/2} \cos \theta \, d\theta \hat{k} \right.$$



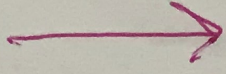
$$x \rightarrow -\infty$$

$$\theta \rightarrow -\pi/2$$

$$x \rightarrow +\infty$$

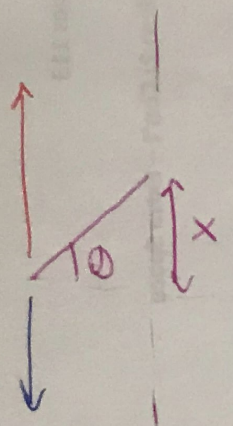
$$\theta \rightarrow +\pi/2$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0 z} \left\{ - \int_{-\pi/2}^{\pi/2} \sin \theta \, d\theta \hat{i} + \int_{-\pi/2}^{\pi/2} \cos \theta \, d\theta \hat{k} \right.$$



$$\vec{E} = \frac{1}{4\pi\epsilon_0 z} \left\{ \right.$$

$$0(-\hat{i}) + 2\hat{k} \left. \right\}$$



$$x \rightarrow -\infty$$

$$\theta \rightarrow -\pi/2$$

$$x \rightarrow +\infty$$

$$\theta \rightarrow +\pi/2$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0 z} \left\{ - \int_{-\pi/2}^{\pi/2} \sin \theta \, d\theta \hat{i} + \int_{-\pi/2}^{\pi/2} \cos \theta \, d\theta \hat{k} \right\}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0 z} \left\{ 0(-\hat{i}) + 2\hat{k} \right\}$$

$$\vec{E} = \frac{\hat{k}}{2\pi\epsilon_0 z}$$