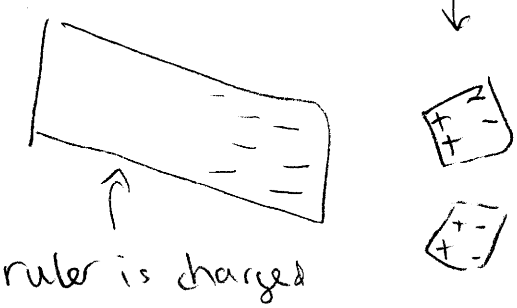
Workshop!

Q5

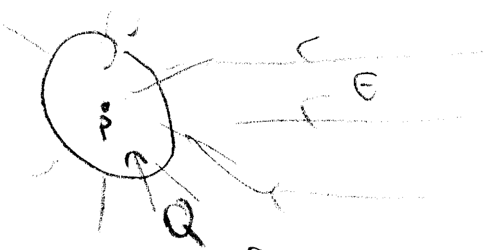


charge separates in paper, and force of attraction is felt btwn paper + ruler.

On a humid day, polar water molecules are attracted to the ruler and neutralize it.

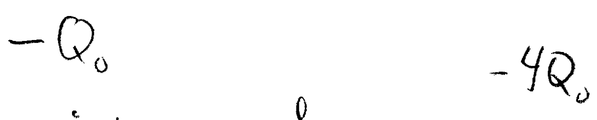
Q14 Large test charges would affect the field

eg

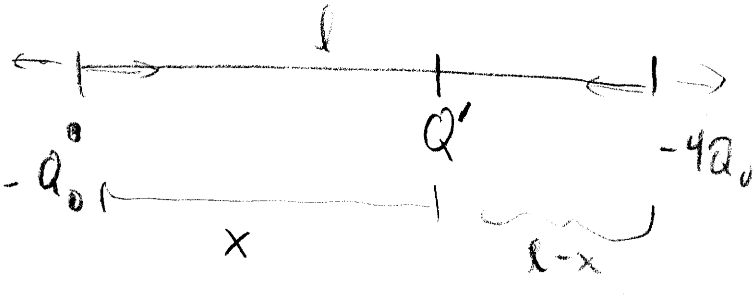


the test charge would effect the field

P18



If the situation is in equilibrium, the additional charge won't move. Clearly the charge must be positive and placed in between the two charges:



what is x?

Since Q' is in equilib, the forces on it are equal:

$$\frac{\cancel{k}Q_0 \cancel{Q'}}{x^2} = -\frac{\cancel{k}4Q_0 \cancel{Q'}}{(l-x)^2}$$

$$4x^2 = (l-x)^2$$

$$4x^2 = l^2 - 2lx + x^2$$

$$3x^2 + 2lx - l^2 = 0$$

$$(3x - l)(x + l) = 0$$

$x = \frac{1}{3}l, -l$ but x must be positive

so $\boxed{x = \frac{1}{3}l}$

what is Q'?

consider force on the left charge:

$$\frac{\cancel{k}\cancel{Q_0} Q'}{x^2} = \angle \frac{\cancel{k}4\cancel{Q_0} Q_0}{l^2}$$

$$Q' = \frac{4Q_0 x^2}{l^2} \quad \text{substitute in } x = \frac{1}{3}l$$

$$= \frac{4Q_0(\frac{1}{3}\cancel{l})^2}{\cancel{l^2}}$$

$$\boxed{Q' = \frac{4}{9}Q_0}$$

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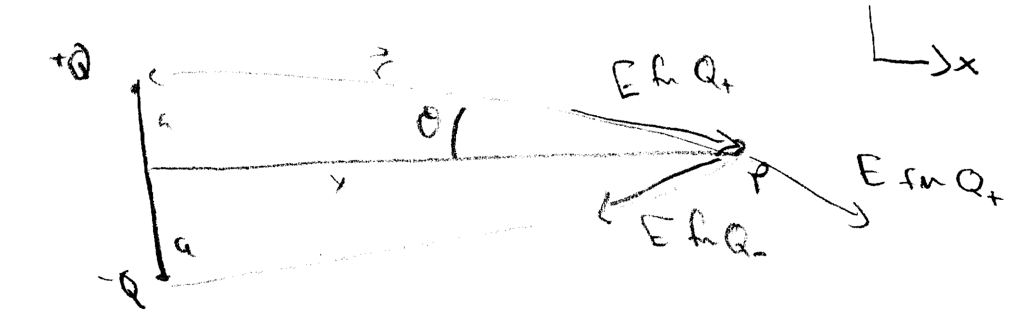


Since charges are the same distance from P and have the same charge, the magnitude of the field from each is the same. Since they are of opposite charge, the x-components should cancel.

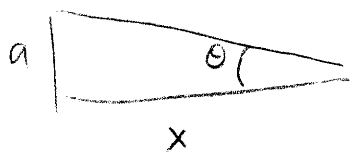
y components

define θ as shown:
y-components of each point down and add

so $\vec{E} = \frac{2kQ}{r^2}\sin\theta(-\hat{j})$

what is r^2? $r^2 = x^2 + a^2$

$$\vec{E} = \frac{2kQ}{x^2+a^2}\sin\theta\,(-\hat{j})$$



$\sin\theta = \frac{a}{(x^2+a^2)^{1/2}}$

$$\boxed{\vec{E} = \frac{2kQa}{(x^2+a^2)^{3/2}}(-\hat{j})}$$

Check x-component

$$\vec{E}_x = \left(\frac{kQ}{(x^2+a^2)^{3/2}} + \frac{k(-Q)}{(x^2+a^2)^{3/2}}\right)\hat{i}$$

field for positive charge; field from neg. charge.

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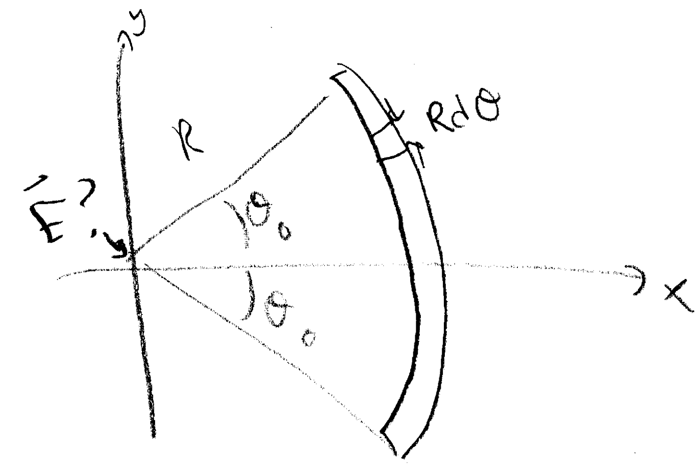

I can see that R remains constant, so it makes sense to use polar coordinates. Arc length $s = r\theta$, so $ds = r\,d\theta$

In this case $dq = \lambda\, d\ell = \lambda R\, d\theta$

By symmetry, the y-components should cancel.

$$dE_y = \frac{k\,dq}{R^2}\sin\theta \qquad dE_x = \frac{k\,dq}{R^2}\cos\theta$$

$$E_x = \int_{-\theta_0}^{\theta_0} \frac{k\,\overbrace{\lambda R\,d\theta}^{dq}}{R^2}\cos\theta$$

$$= \frac{k\lambda}{R}\int_{-\theta_0}^{\theta_0}\cos\theta\, d\theta$$

$$= \frac{k\lambda}{R}\left[\sin\theta_0 - \sin(-\theta_0)\right] \qquad \text{but } \sin(-\theta) = -\sin\theta$$

$$= \frac{2k\lambda\sin\theta_0}{R}$$

$$\boxed{\vec{E} = \frac{-2k\lambda\sin\theta_0}{R}\,\hat{i}}$$