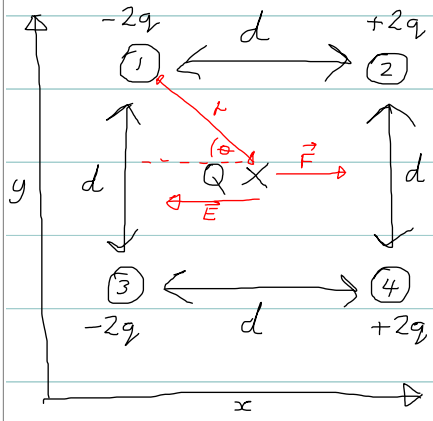

A POINT CHARGE OF $Q=-123.456789\,nC$ IS PLACED AT THE EXACT CENTER OF A SQUARE OF 4 CHARGES, AS SHOWN IN THE DIAGRAM. IF $q=1C$ AND $d=1m$, (1) WHAT IS THE MAGNITUDE AND DIRECTION OF THE RESULTING ELECTRIC FIELD? (2) WHAT IS THE MAGNITUDE AND DIRECTION OF THE RESULTING FORCE? (3) BONUS AFTER WEEK 3! WHAT ARE THE DIRECTIONS OF INCREASING POTENTIAL AND INCREASING POTENTIAL ENERGY?

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(1) IT SAVES TIME TO REALIZE THAT THE SYMMETRY IMPLIES THAT THE E-FIELD (THE DIRECTION THAT A POSITIVE CHARGE WILL MOVE IS LEFT, AS THE Y-COMPONENTS ARE IN BALANCE, SO $F_y=0$ BY INSPECTION

$|E_1|=\frac{2kq}{r^2}$ WHERE $r^2=\left(\frac{d}{2}\right)^2+\left(\frac{d}{2}\right)^2=\frac{2d^2}{4}=\frac{d^2}{2}\Rightarrow|E_1|=\frac{4kq}{d^2}$, $E_1^x=|E_1|\cos\theta=|E_1|\frac{d}{2r}=|E_1|\frac{d}{2\sqrt{\frac{d^2}{2}}}=\frac{|E_1|}{\sqrt{2}}(-\hat{i})$

So, substituting in for $|E_1|$, $E_1^x=\frac{4kq}{\sqrt{2}d^2}(-\hat{i})=\frac{2\sqrt{2}kq}{d^2}(-\hat{i})$

By inspection, $E_1^x=E_2^x=E_3^x=E_4^x\Rightarrow E_x=4E_1^x=\frac{8\sqrt{2}kq}{d^2}(-\hat{i})$. So, $\vec{E}=-8\sqrt{2}k\hat{i}\ NC^{-1}$

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(2) IN GENERAL, WITH ALL ELECTROSTATICS PROBLEMS ITS EASIEST TO FIND THE FIELD AND THEN SUB IN THE TEST CHARGE TO GET THE FORCE. MY DUMB CHOICE OF $Q=-123.456789\,nC$ SHOWS WHY. So, $\vec{F}=\vec{E}Q=-8\sqrt{2}k(-123.456789)\times10^{-9}\hat{i}\ N$

and, $\vec{F}=8\sqrt{2}k(123.456789)\times10^{-9}\hat{i}\ N$. (BECAUSE Q IS NEGATIVE!) NOTE THAT $\vec{F}$ AND $\vec{E}$ POINT IN OPPOSITE DIRECTIONS

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(3) THE E-FIELD POINTS FROM HIGH TO LOW POTENTIAL SO THE POTENTIAL INCREASES IN THE POSITIVE $\hat{i}$ DIRECTION. THE FORCE POINTS FROM HIGH TO LOW POTENTIAL ENERGY SO THE POTENTIAL ENERGY INCREASES IN THE NEGATIVE $\hat{i}$ DIRECTION