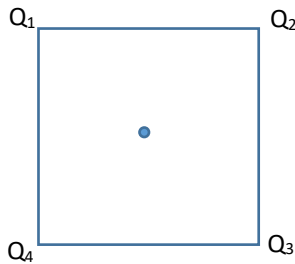


Assignment 1: ELECTRICITY

Released: Friday Jan. 18

Due: Fri Friday Jan 25 6:00PM

- 1 4 charges of $Q_1=1\text{nC}$, $Q_2=2\text{nC}$, $Q_3=3\text{nC}$, and $Q_4=4\text{nC}$ are placed at the vertices of a square of side 1m. Q_1 is in the top left corner, Q_2 is in the top right corner, Q_3 is in the bottom right corner and the Q_4 in the bottom left corner. Find the magnitude of electric field at the center of the square. On the Q_4 - Q_2 diagonal the Field E is pointing toward Q_2 and has magnitude of 36N/C. On the Q_1 - Q_3 diagonal the Field E is pointing toward Q_1 and has magnitude of 36N/C.

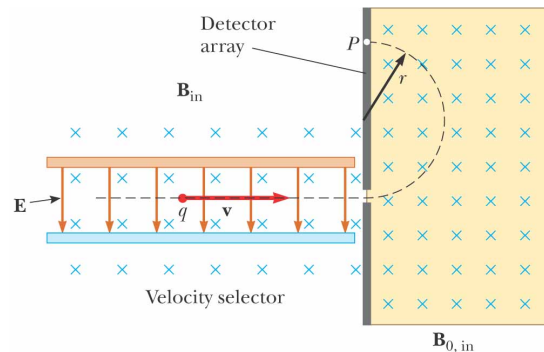


The magnitude of the force is given by the $\sqrt{36^2 + 36^2} = 50.9\text{N/C}$

- 2 X-Ray lamp accelerates the electrons in the potential difference of 1kV. Find the lowest wavelength of the X rays emitted by this lamp.

$$eV = h \frac{c}{\lambda_{\min}} \Rightarrow \lambda_{\min} = h \frac{c}{eV} = 6.626 \times 10^{-34} \frac{2.998 \times 10^8}{1000 \times 1.6 \times 10^{-19}} \text{m} = 0.0124 \times 10^{-7} \text{m} = 1.24\text{nm}$$

- 3 In the standard Mass Spectrometer Setup before entering the magnetic field zone where its trajectory is determined by the Lorentz Force the charged particles pass through the velocity selector. In it, the electric force acts on particles in the direction opposite to the magnetic force. After travelling along the straight line in the velocity selector employing E-field of magnitude of 2000N/C, the carbon ion (^{12}C)⁺ travels inside the spectrometer along the circular path of radius $r=0.5\text{m}$. Find the velocity of the ion as it leave the velocity selector. (B field is constant throughout the apparatus)



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SOLUTION:

In the Wien's Filter:

$$eE = evB$$

In the Magnetic field zone:

$$evB = \frac{mv^2}{r}$$

Combining the two equations: $evB = \frac{mv^2}{r} \Rightarrow eB = \frac{mv}{r} \Rightarrow \frac{eE}{v} = \frac{mv}{r} \Rightarrow mv^2 = eEr$

$$\Rightarrow v = \sqrt{\frac{eEr}{m}} = 9.82 \text{ km/s}$$

- 4 Find the Electric Field originating from the disk of radius R and charge Q at the distance z above its centre. **Use this result to obtain expression for the electric field at distance z from the infinite plane.** Use opposite side of this page to provide the full derivation. Make sure that you include the large diagram with clearly stated variables, angles etc.

Assignment 1: ELECTRICITY CONT.

5. Find the electric field due the square made of 4 rods of length $L=10\text{cm}$ and charge of $Q=2\text{nC}$ each, point P at distance $D=7\text{ cm}$ above the center of the square.

To answer we should find the magnitude of the electric field at point P from single rod.

Point P is at distance z from the rod $z = \sqrt{\left(\frac{L}{2}\right)^2 + D^2} = \sqrt{(0.025)^2 + (0.07)^2} = 0.0743\text{m}$

We will use the expression for E field from a single charged rod at distance $z=0.0743\text{m}$

$$E(z) = \frac{k_e Q}{z} \frac{1}{\sqrt{(y)^2 + \left(\frac{L}{2}\right)^2}} = \frac{(8.99 \times 10^9)(4 \times 10^{-9})}{0.0743} \frac{1}{0.0784} \frac{N}{C} = 6174 \frac{N}{C}$$

The rest is based on the symmetry of this situation (diagram discussed in class!) and not presented here:

$$E_{\perp} = 4|E|\cos\theta = 4 \frac{D}{\sqrt{(D)^2 + \left(\frac{L}{2}\right)^2}} |E| = 232667 \frac{N}{C} \quad E_{\parallel} = 0$$

6. Uniformly charged rod ($q=62\text{nC}$) of length 31cm is bend into the shape of a circular hoop of 5cm radius. It is done in such a way that there is no charge lost. As result the hoop has a 0.42cm gap. Find the Electric field at the centre of this hoop.

i) This object may be treated as superposition of (1) fully charged ring with (2) the small straight segment of length $d=0.42\text{cm}$ with negative charge $Q = -\lambda d = -\frac{0.42}{31} \times 62\text{nC} = -0.84\text{nC}$

ii) Since (1) produces 0 field at the center (symmetry!!!), the resulting electric field is due to (2) only.

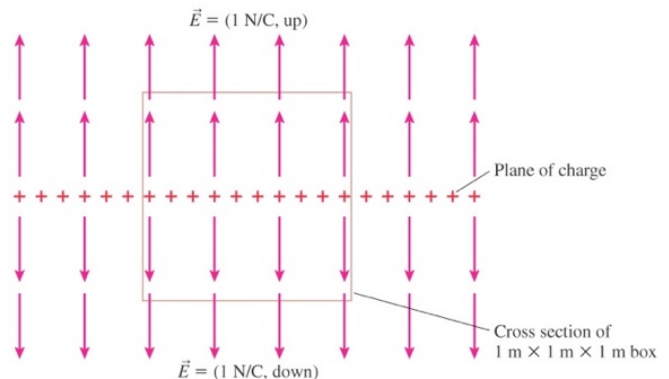
iii) We need to find the field from the short rod of length $L=0.42\text{cm}$ and charge Q of $-\frac{0.42}{31} \times 62\text{nC} = -0.84\text{nC}$ at distance $r=5\text{cm}$ from its center. We may use one of the expressions we obtained last week:

$$E(r) = -\frac{k_e Q}{r} \frac{1}{\sqrt{(r)^2 + \left(\frac{L}{2}\right)^2}} = -\frac{(8.99 \times 10^9)(0.84 \times 10^{-9})}{0.05} \frac{1}{0.05004} \frac{N}{C} = -3018 \frac{N}{C}$$

7. i) The total electric flux through this box is:

ANS: 2 N/C m^2

8. A vertical electric field of magnitude $2.00 \times 10^4\text{ N/C}$ exists above the Earth's surface on a day when a thunderstorm is brewing. A car covers a rectangle measuring 6.00 m by 3.00 m on the roadway below it, which is built on dry fill. The roadway slopes downward at 10.0° . Determine the electric flux through the bottom of the car.



$$\Phi_E = EA \cos\theta = (2.00 \times 10^4\text{ N/C})(18.0\text{ m}^2) \cos 10.0^\circ = \boxed{355\text{ kN}\cdot\text{m}^2/\text{C}}$$