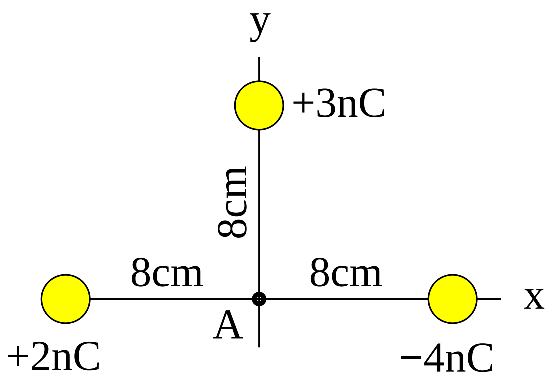
Unit Exam I: Problem #1 (Spring '18)

Consider the three point charges surrounding point A or point B.
Find the electric field $\mathbf{E}_A$ at point A and $\mathbf{E}_B$ at point B.
Find the electric potential V_A at point A and V_B at point B.
Find the magnitude F_{23} between the two positive charges on the left and F_{35} between the two positive charges on the right.



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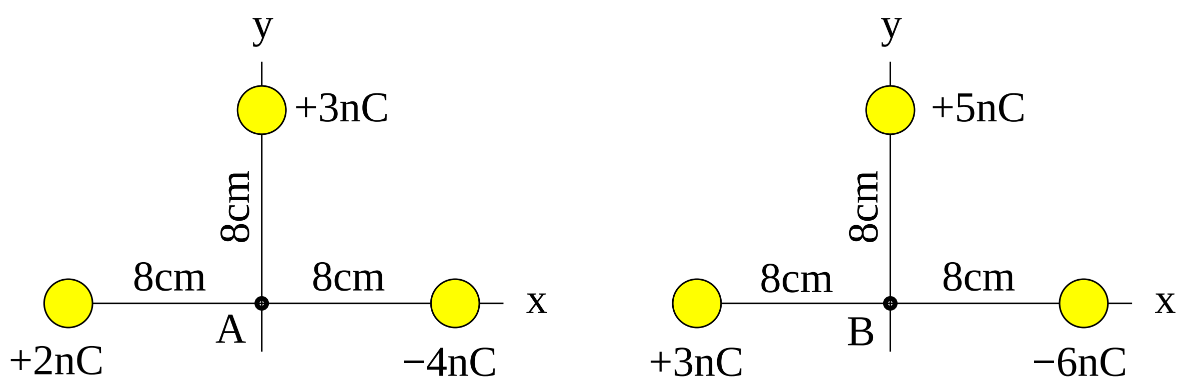


Solution:

- $\mathbf{E}_A = k\dfrac{|2\text{nC}|}{(8\text{cm})^2}\,\hat{\mathbf{i}} + k\dfrac{|4\text{nC}|}{(8\text{cm})^2}\,\hat{\mathbf{i}} - k\dfrac{|3\text{nC}|}{(8\text{cm})^2}\,\hat{\mathbf{j}} = 8.44\times10^3\,\text{N/C}\,\hat{\mathbf{i}} - 4.22\times10^3\,\text{N/C}\,\hat{\mathbf{j}}$

  $\mathbf{E}_B = k\dfrac{|3\text{nC}|}{(8\text{cm})^2}\,\hat{\mathbf{i}} + k\dfrac{|6\text{nC}|}{(8\text{cm})^2}\,\hat{\mathbf{i}} - k\dfrac{|5\text{nC}|}{(8\text{cm})^2}\,\hat{\mathbf{j}} = 12.7\times10^3\,\text{N/C}\,\hat{\mathbf{i}} - 7.03\times10^3\,\text{N/C}\,\hat{\mathbf{j}}$

- $V_A = k\dfrac{2\text{nC}}{8\text{cm}} + k\dfrac{3\text{nC}}{8\text{cm}} - k\dfrac{4\text{nC}}{8\text{cm}} = 113\text{V}, \quad V_B = k\dfrac{3\text{nC}}{8\text{cm}} + k\dfrac{5\text{nC}}{8\text{cm}} - k\dfrac{6\text{nC}}{8\text{cm}} = 225\text{V}$

- $F_{23} = k\dfrac{|(2\text{nC})(3\text{nC})|}{(8\text{cm})^2+(8\text{cm})^2} = 4.22\times10^{-6}\,\text{N}, \quad F_{35} = k\dfrac{|(3\text{nC})(5\text{nC})|}{(8\text{cm})^2+(8\text{cm})^2} = 10.5\times10^{-6}\,\text{N}$

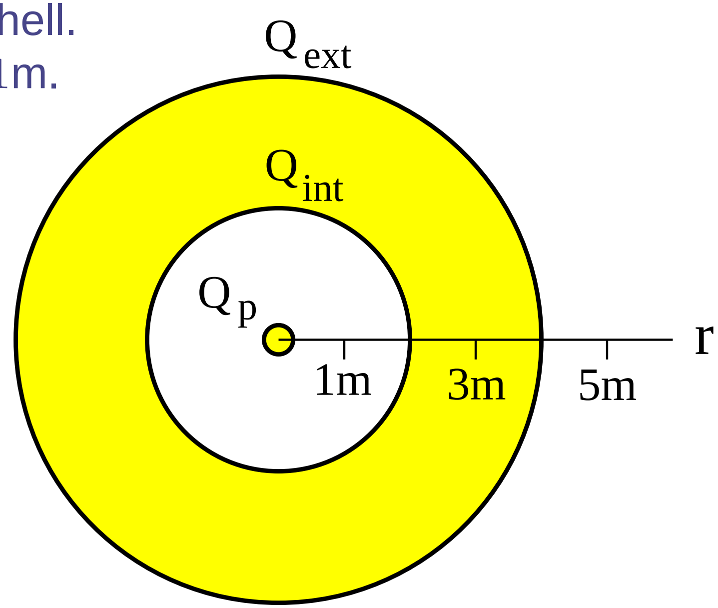
Unit Exam I: Problem #2 (Spring ’18)

The conducting spherical shell with no net charge on it has a 2m inner radius and a 4m outer radius. There is a point charge $Q_\mathrm{p} = -4\mathrm{nC}$ [$Q_\mathrm{p} = 5\mathrm{nC}$] at the center.

(a) Find the charges Q_int and Q_ext on the two surfaces of the shell.

(b) Find the electric flux Φ_E through a Gaussian sphere of $r = 1$m.

(c) Find magnitude and direction of the electric field at $r = 5$m.



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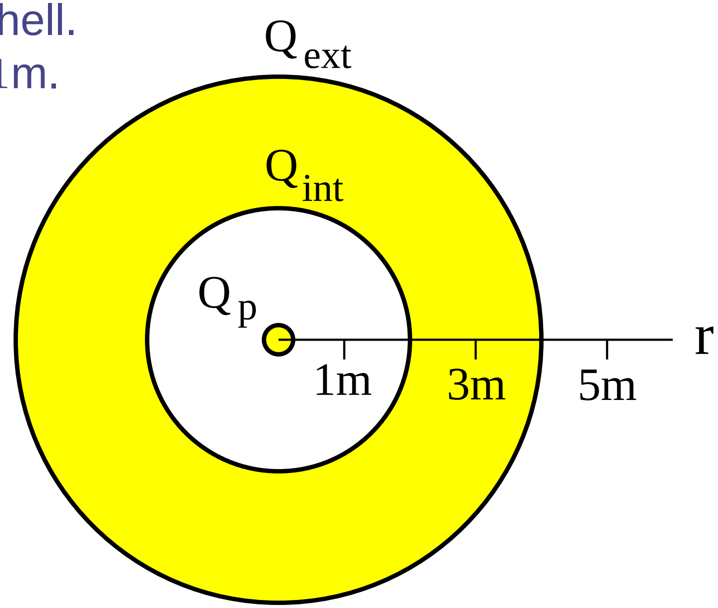


Solution:

(a) $Q_\mathrm{int} = +4\mathrm{nC}, \quad Q_\mathrm{ext} = -4\mathrm{nC},$
$[Q_\mathrm{int} = -5\mathrm{nC}, \quad Q_\mathrm{ext} = +5\mathrm{nC}]$.

(b) $\Phi_E = \dfrac{Q_\mathrm{p}}{\epsilon_0} = -452\mathrm{Nm}^2/\mathrm{C},$

$$\left[\Phi_E = \frac{Q_\mathrm{p}}{\epsilon_0} = +565\mathrm{Nm}^2/\mathrm{C}\right].$$

(c) $4\pi(5m)^2 E = \dfrac{(Q_\mathrm{p} + Q_\mathrm{int} + Q_\mathrm{ext})}{\epsilon_0} < 0 \quad \Rightarrow \; E = -1.44\mathrm{N/C} \quad (\mathrm{inward}),$

$$\left[4\pi(5m)^2 E = \frac{(Q_\mathrm{p} + Q_\mathrm{int} + Q_\mathrm{ext})}{\epsilon_0} > 0 \quad \Rightarrow \; E = +1.80\mathrm{N/C} \quad (\mathrm{outward})\right].$$

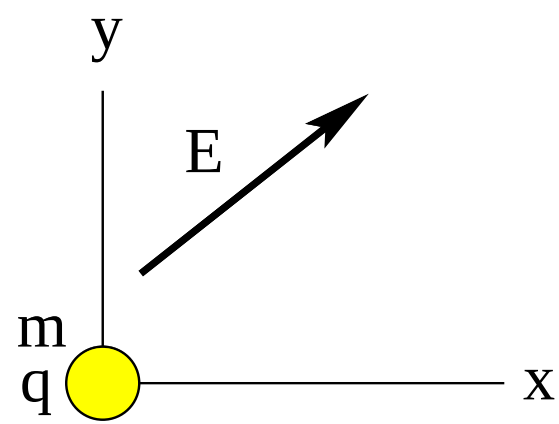
Unit Exam I: Problem #3 (Spring '18)

In a region of uniform electric field, $\mathbf{E} = 5\mathrm{N/C}\,\hat{\mathbf{i}} + 4\mathrm{N/C}\,\hat{\mathbf{j}}$, a charged particle $(m = 0.03\mathrm{kg},\ q = 2\mathrm{mC})$ [$(m = 0.02\mathrm{kg},\ q = 3\mathrm{mC})$] is released from rest at time $t = 0$ at the origin of the coordinate system.

(a) Find the electric force $\mathbf{F} = F_x\,\hat{\mathbf{i}} + F_y\,\hat{\mathbf{j}}$ acting on the particle.

(b) Find the position $\mathbf{r} = x\,\hat{\mathbf{i}} + y\,\hat{\mathbf{j}}$ of the particle at time $t = 7\mathrm{s}$.

(c) Draw the shape of the path into the diagram.



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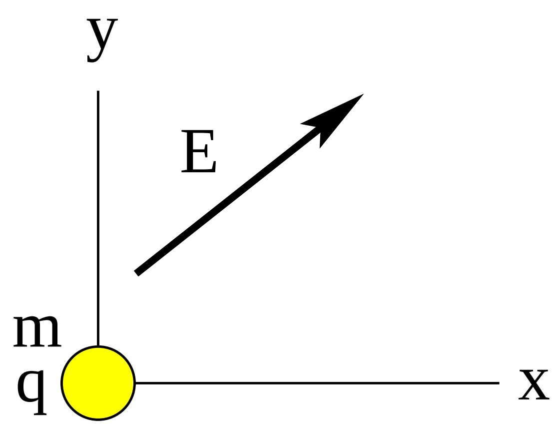
(a) Find the electric force $\mathbf{F} = F_x\,\hat{\mathbf{i}} + F_y\,\hat{\mathbf{j}}$ acting on the particle.

(b) Find the position $\mathbf{r} = x\,\hat{\mathbf{i}} + y\,\hat{\mathbf{j}}$ of the particle at time $t = 7$s.

(c) Draw the shape of the path into the diagram.



Solution:

(a) $F_x = (2\times10^{-3}\mathrm{C})(5\mathrm{N/C}) = 10\times10^{-3}\mathrm{N}, \quad F_y = (2\times10^{-3}\mathrm{C})(4\mathrm{N/C}) = 8\times10^{-3}\mathrm{N}.$

$\left[F_x = (3\times10^{-3}\mathrm{C})(5\mathrm{N/C}) = 15\times10^{-3}\mathrm{N}, \quad F_y = (3\times10^{-3}\mathrm{C})(4\mathrm{N/C}) = 12\times10^{-3}\mathrm{N}.\right]$

(b) $$x = \frac{1}{2}\left(\frac{10\times10^{-3}\mathrm{N}}{3\times10^{-2}\mathrm{kg}}\right)(7s)^2 = 8.17\mathrm{m}, \quad y = \frac{1}{2}\left(\frac{8\times10^{-3}\mathrm{N}}{3\times10^{-2}\mathrm{kg}}\right)(7s)^2 = 6.53\mathrm{m}.$$

$$\left[x = \frac{1}{2}\left(\frac{15\times10^{-3}\mathrm{N}}{2\times10^{-2}\mathrm{kg}}\right)(7s)^2 = 18.4\mathrm{m}, \quad y = \frac{1}{2}\left(\frac{12\times10^{-3}\mathrm{N}}{2\times10^{-2}\mathrm{kg}}\right)(7s)^2 = 14.7\mathrm{m}.\right]$$

(c) Straight line through origin parallel to direction of electric field.