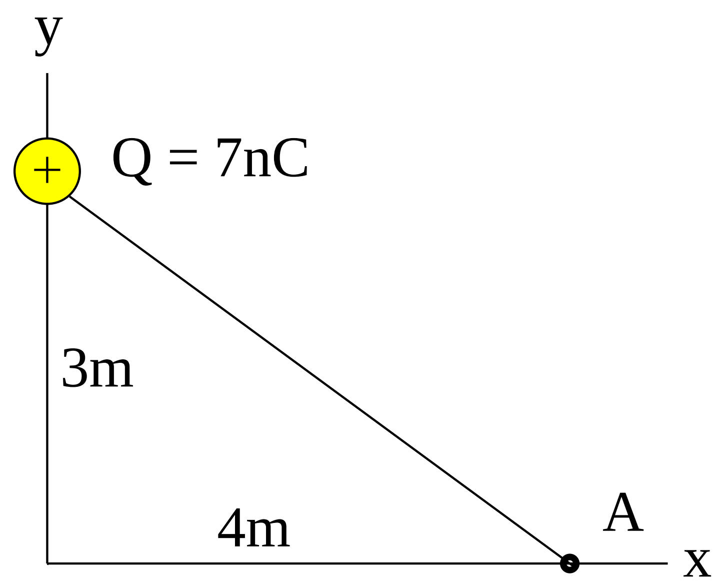
Unit Exam I: Problem #1 (Spring ’11)

The point charge Q has a fixed position as shown.
(a) Find the components E_x and E_y of the electric field at point A.
(b) Find the electric potential V at point A.
Now place a proton $(m = 1.67 \times 10^{-27}\mathrm{kg},\ q = 1.60 \times 10^{-19}\mathrm{C})$ at point A.
(c) Find the the electric force F (magnitude only) experienced by the proton.
(d) Find the electric potential energy U of the proton.



Solution:

(a) $E = k\dfrac{|7\mathrm{nC}|}{(5\mathrm{m})^2} = 2.52\mathrm{N/C}$,

$$E_x = \frac{4}{5}E = 2.02\mathrm{N/C}, \quad E_y = -\frac{3}{5}E = -1.51\mathrm{N/C}$$

(b) $V = k\dfrac{7\mathrm{nC}}{5\mathrm{m}} = 12.6\mathrm{V}$.

(c) $F = qE = 4.03 \times 10^{-19}\mathrm{N}$.

(d) $U = qV = 2.02 \times 10^{-18}\mathrm{J}$.

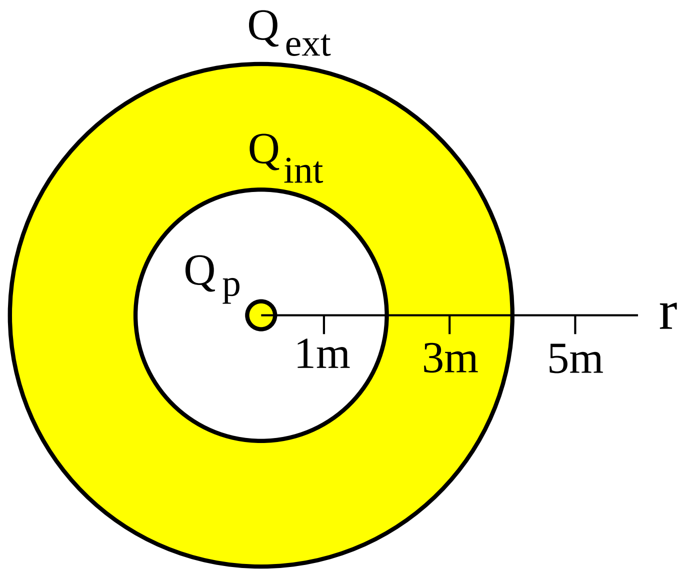
The charged conducting spherical shell has a 2m inner radius and a 4m outer radius. The charge on the outer surface is $Q_{\rm ext} = 8{\rm nC}$. There is a point charge $Q_{\rm p} = 3{\rm nC}$ at the center.

(a) Find the charge $Q_{\rm int}$ on the inner surface of the shell.

(b) Find the surface charge density $\sigma_{\rm ext}$ on the outer surface of the shell.

(c) Find the electric flux Φ_E through a Gaussian sphere of radius $r = 5$m.

(d) Find the magnitude of the electric field E at radius $r = 3$m.



Solution:

(a) $Q_{\rm int} = -Q_{\rm p} = -3{\rm nC}.$

(b) $\sigma_{\rm ext} = \dfrac{Q_{\rm ext}}{4\pi(4{\rm m})^2} = 3.98 \times 10^{-11}{\rm C/m^2}.$

(c) $\Phi_E = \dfrac{Q_{\rm ext}}{\epsilon_0} = 904{\rm Nm^2/C}.$

(d) $E = 0$ inside conductor.

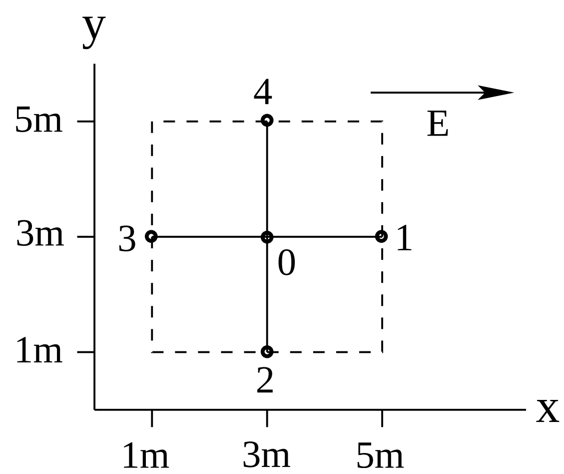
Unit Exam I: Problem #3 (Spring '11)

Consider a region of space with a uniform electric field $\mathbf{E} = 0.5\mathrm{V/m}\,\hat{\mathbf{i}}$. Ignore gravity.

(a) If the electric potential vanishes at point 0, what are the electric potentials at points 1 and 2?

(b) If an electron ($m = 9.11 \times 10^{-31}$kg, $q = -1.60 \times 10^{-19}$C) is released from rest at point 0, toward which point will it start moving?

(c) What will be the speed of the electron when it gets there?



Solution:

(a) $V_1 = -(0.5\mathrm{V/m})(2\mathrm{m}) = -1\mathrm{V}, \quad V_2 = 0.$

(b) $\mathbf{F} = q\mathbf{E} = -|qE|\hat{\mathbf{i}}$ (toward point 3).

(c) $\Delta V = (V_3 - V_0) = 1\mathrm{V}, \quad \Delta U = q\Delta V = -1.60 \times 10^{-19}\mathrm{J},$

$K = -\Delta U = 1.60 \times 10^{-19}\mathrm{J}, \quad v = \sqrt{\frac{2K}{m}} = 5.93 \times 10^5\mathrm{m/s}.$

Alternatively:

$F = qE = 8.00 \times 10^{-20}\mathrm{N}, \quad a = \frac{F}{m} = 8.78 \times 10^{10}\mathrm{m/s^2},$

$|\Delta x| = 2\mathrm{m}, \quad v = \sqrt{2a|\Delta x|} = 5.93 \times 10^5\mathrm{m/s}.$