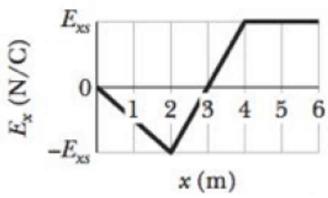
PHYS 102: General Physics KOÇ UNIVERSITY Spring Semester 2012
College of Arts and Sciences
Quiz 3 March 1, 2012

Closed book. No calculators are to be used for this quiz.

Name: Student ID: Signature:

Q. A graph of the x component of the electric field as a function of x in a region of space is shown in the figure below. The scale of the vertical axis is set by $E_{xs} = 20.0\,\text{N/C}$. The y and z components of the electric field are zero. If the electric potential at the origin is 10 V, what is the electic potential at $x = 2.0\,\text{m}$? Where is the electric potential zero?



$$V_a - V_b = \int_a^b \vec{E}.d\vec{l} \Rightarrow V_0 - V_f = \int_0^{x_f} E_x dx$$

Note that integral is area under the graph:

$$10V - V_2 = \frac{-2 \times 20}{2} = -20V \Rightarrow -V_2 = -30V \Rightarrow V_2 = 30V$$

Assume potential is zero at point x_0 . Then :

$$10V - V_{x_0} = \int_0^{x_0} E_x dx = \int_0^3 E_x dx + \int_3^4 E_x dx + \int_4^{x_0}$$

$$\Rightarrow 10V = \frac{-3 \times 20}{2} V + 20/2V + 20\frac{V}{m}(X_0 - 4m) \Rightarrow$$

$$\Rightarrow 10V = -30V + 10V + 20\frac{V}{m}(x_0 - 4m) \Rightarrow x_0 = 5.5m$$

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Q. A charge of magnitude Q is located at the position $(a, 0, 0)$ while another charge of magnitude $-2Q$ is located at $(0, a, 0)$. Find the magnitude of the third charge at the origin if the total potential energy (self energy) of the given charge configuration is zero.

$q_1 = -2Q$, $q_2 = Q$ and the unknown charge q_0

$$U_{total} = U_{01} + U_{02} + U_{12} = 0$$

$$where$$

$$U_{ij} = \frac{q_i q_j}{4\pi\epsilon_0 r_{ij}}$$

$$U_{01} + U_{02} + U_{12} = \frac{Q}{4\pi\epsilon_0 a}(-2q - \frac{2Q}{\sqrt(2)} + q) = 0 \Rightarrow$$

$$(-q - \frac{2Q}{\sqrt(2)}) = 0 \Rightarrow q = -\sqrt(2)Q$$

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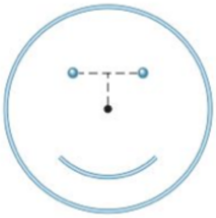
Q. The smiling face below consists of three items:
1. a thin rod of charge -3.0μC that forms a full circle of radius 6.0 cm;
2. a second thin rod of charge 2.0μC that forms a circular arc of radius 4.0 cm, covering an angle of $90°$ about the center;
3. an electic dipole with a dipole moment that is perpendicular to a radial line and has magnitude 1.28×10^{-21} C·m.
What is the electric potential at the center?



First note that, the dipole's contribution to the total electric potential at the center is zero (the two point charges with opposite sign and equal magnitude are at the same distance from the origin)

The arc and the circle carry charges located at a fixed distance to the center, therefore,

$$V_{circle} = k\frac{Q_c}{r_c}(Q_c = -3.0\mu C, r_c = 6.0cm)$$

$$V_{arc} = k\frac{Q_a}{r_a}(Q_a = 2.0\mu C, r_a = 4.0cm)$$

$$\Rightarrow V_{Total} = V_{circle} + V_{arc} + V_{dipole} = k(\frac{Q_c}{r_c} + \frac{Q_a}{r_a}) = 0$$

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Q. A conducting sphere with mass m, radius r and a net electric charge Q is brought into contact with a neutral but otherwise identical sphere. Explain what will happen when the spheres are let free and find their speed after a long time.

The charge will be distributed equally to the spheres because they have the same radius. The initial electrical potential energy will be converted to kinetic energy when the two spheres get infinitely far away from each others, the electrostatic repulsion of like charges on them.

$$U_1 = \frac{Q^2}{32\pi\epsilon_0 r}$$

$$U_i + K_i = U_f + K_f = U_i + 0 = 0 + K_f$$

$$U_i = K_f$$

$$\frac{Q^2}{32\pi\epsilon_0 r} = 1/2mV^2 \times 2 \Rightarrow$$

$$V^2 = \frac{Q^2}{32\pi\epsilon_0 mr} \Rightarrow$$

$$V = \frac{Q}{4\sqrt{(2\pi\epsilon_0 mr)}}$$

What is the electric potential at a distance x from the origin of a uniformly charged ring, which has total charge Q and radius R.

$$
\begin{aligned}
dV &= \frac{dq}{4\pi\epsilon_0 r} \Rightarrow \\
dV &= \frac{dQ}{4\pi\epsilon_0\sqrt{(x^2+R^2)}} = \frac{1}{4\pi\epsilon_0\sqrt{(x^2+R^2)}}\oint dQ \\
&= \frac{Q}{4\pi\epsilon_0\sqrt{(x^2+R^2)}}
\end{aligned}
$$

Alternatively,

$$
\begin{aligned}
dQ &= \lambda R d\theta \\
\lambda &= \frac{Q}{2\pi R} \\
dV &= \frac{\lambda R d\theta}{4\pi\epsilon_0\sqrt{(x^2+R^2)}} \\
&= \frac{QRd\theta}{8\pi^2\epsilon_0\sqrt{(x^2+R^2)}}
\end{aligned}
$$

$$
\begin{aligned}
V = \int dV &= \int_0^{2\pi} \frac{QRd\theta}{8\pi^2\epsilon_0 R\sqrt{(x^2+R^2)}} \\
\Rightarrow V &= \frac{Q}{4\pi\epsilon_0\sqrt{(x^2+R^2)}}
\end{aligned}
$$