Answer on Question #55895, Physics / Electromagnetism

What are the dimensions of the constant k in Coulomb's law of electrostatics?

$\mathrm{ML^2T^{-4}T^{-2}A^{-1}}$

$\mathrm{ML^2T^3A^{-2}}$

$\mathrm{M^{-2}L^3T^2A^{-1}}$

$\mathbf{\underline{ML^3T^{-4}A^{-2}}}$

Solution:

According to Coulomb's law, two point charges interact with each other in a vacuum with a force F whose magnitude is proportional to the product of the charges e_1 and e_2 and inversely proportional to the square of the distance r between them:

$$\mathrm{F = k\frac{e_1 e_2}{r^2}}$$

Or

$$\mathrm{F = k\frac{q_1 q_2}{r^2}}$$

The proportionality constant k is called the electrostatic constant. The constant k is a proportionality factor that depends on the system of units chosen: in the absolute (Gaussian) system of units (the CGS system), k = 1; in the International System of Units (SI), $k = \frac{1}{4\pi\epsilon_0}$, where ϵ_0 is the electric constant. The force F is directed along a straight line connecting the charges and is attractive for unlike charges (F < 0) and repulsive for like charges (F > 0); $\mathrm{e_1 and\ e_2}$ - magnitude of charge 1 and charge 2; r is the distance between two charges.

From the noted above formula, we can express the constant k:

$$\mathrm{k = \frac{Fr^2}{q_1 q_2}}$$

Now, we need to express each term in the formula for constant k.

In accordance with the Newton's second law of motion, the force is equal:

$$\mathrm{F = ma}$$

The dimensions of force are

$$\mathrm{\frac{[M][L]}{T^2}}$$

When electric current flows for a specified time, we can calculate the charge:

$$\mathrm{Q = I \cdot t}$$

Where

Q is the electric charge, measured in coulombs $[\mathrm{C}]$.

I is the current, measured in amperes $[\mathrm{A}]$.

t is the time period, measured in seconds $[\mathrm{s}]$.

Thus, we can write the following:

$$[\mathrm{C}] = [\mathrm{A}][\mathrm{s}]$$

Now, we can substitute the noted above dimensions in order to express the dimensions of constant k:

$$[\mathrm{k}] = \frac{\frac{[\mathrm{M}][\mathrm{L}]}{\mathrm{T}^2} \cdot \frac{[\mathrm{L}]^2}{1}}{([\mathrm{A}][\mathrm{T}])^2}$$

Simplify the obtained expression:

$$[\mathrm{k}] = \frac{\frac{[\mathrm{M}][\mathrm{L}]}{\mathrm{T}^2} \cdot \frac{[\mathrm{L}]^2}{1}}{([\mathrm{A}][\mathrm{T}])^2} = \frac{[\mathrm{M}][\mathrm{L}]^3}{[\mathrm{A}]^2[\mathrm{T}]^4} = \mathrm{ML}^3\mathrm{A}^{-2}\mathrm{T}^{-4}$$

Finally, we obtain the dimensions of the constant k are equal to $[\mathrm{k}] = \mathrm{ML}^3\mathrm{A}^{-2}\mathrm{T}^{-4}$

Thus, we can highlight the answer is $\mathrm{ML}^3\mathrm{T}^{-4}\mathrm{A}^{-2}$.