Answer on Question #79707 - Physics - Electric Circuits

A positive 20μC charge is placed at the centre of a circle of radius 20 cm. If we move a positive 2μC charge once along the circumference of the circle, will any work be done in the process? Justify your answer.

Solution

Write an expression for the electric field created by the main charge $Q = 20\ \mu\text{C}$ at a distance $r = 20\ \text{cm}$:

$$\boldsymbol{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\frac{\boldsymbol{r}}{r}$$

where $\boldsymbol{r}$ is the vector which comes from the first charge to any direction. We see thus that the charge creates an electrostatic field. In a plane of the circle vectors $\boldsymbol{E}$ are directed from centre of the circle (where the charge is located) to its circumference.

During the process of motion of $q = 2\ \mu\text{C}$ charge the work done is

$$W = q\int_a^b \boldsymbol{E}\cdot d\boldsymbol{l}$$

where $d\boldsymbol{l}$ is the displacement of the second charge. $\boldsymbol{E}\cdot d\boldsymbol{l}$ is a scalar product of $\boldsymbol{E}$ and $d\boldsymbol{l}$ and

$$\boldsymbol{E}\cdot d\boldsymbol{l} = \|\boldsymbol{E}\|\cdot\|d\boldsymbol{l}\|\cdot\cos(\boldsymbol{E}, d\boldsymbol{l})$$

where $\cos(\boldsymbol{E}, d\boldsymbol{l})$ is a cosine of the angle between $\boldsymbol{E}$ and $d\boldsymbol{l}$.

Since the second charge is *moved once along the circumference*, $d\boldsymbol{l}$ is always perpendicular to $\boldsymbol{E}$ (it means that $\cos(\boldsymbol{E}, d\boldsymbol{l}) = \cos 90° = 0$) and $a = b$ (it means that the integral is equal to 0), for these two reasons $W = 0$. The second charge is moved along the *equipotential lines*.

Answer

$W = 0$ because the second charge is moved once along the circumference with the first charge in centre. It means that:

1) vectors $\boldsymbol{E}, d\boldsymbol{l}$ are always perpendicular to each other and the integral above is 0;

2) $a = b$, that is why the integral above is equal to 0.