Department of Physics
Year 1 Tutorials
Module Phys123
Electricity and Magnetism

Answers for Tutorial 3

The marks to be awarded for each question are indicated in square brackets.

Problem 1 [10]

Magnitude of electric field $E = \sqrt{1^2 + (-2)^2 + (-1)^2} = \sqrt{6} = 2.45\,\mathrm{V\,m^{-1}}$ [2]

Distance moved $r = \sqrt{3^2 + 2^2 + (-1)^2} = \sqrt{14} = 3.74\,\mathrm{m}$ [2]

Work done $W = \vec{F}\cdot\vec{r} = q\vec{E}\cdot\vec{r}$ [2]

Hence $W = 7\times10^{-9}\times\left(3\times1 + 2\times(-2) + (-1)\times(-1)\right) = 0$ [2]

No work done because movement of charge is perpendicular to direction of E field [2]

Problem 2 [10]

Vector describing particle's motion $\vec{r} = \vec{r}_2 - \vec{r}_1$ [2]

$$\vec{r} = \begin{pmatrix}-1\\-1\\0\end{pmatrix} - \begin{pmatrix}1\\-1\\3\end{pmatrix} = \begin{pmatrix}-2\\0\\-3\end{pmatrix}\mathrm{m}$$ [2]

Work done $W = q\vec{E}\cdot\vec{r} = 9\times10^{-6}\times(-4+0+3) = -9\times10^{-6}\,\mathrm{J}$ [2]

Angle θ from $\cos\theta = \dfrac{\vec{E}\cdot\vec{r}}{|\vec{E}||\vec{r}|} = \dfrac{-4+0+3}{\sqrt{4+4+1}\sqrt{4+0+9}} = -0.0925$ [3]

Hence $\theta = 1.66\,\mathrm{rad}$ or 95.1° [1]

Problem 3 [5]

Torque $\vec{\tau} = \vec{p}\times\vec{E}$ [2]

$$\vec{p}\times\vec{E} = \begin{vmatrix}\hat{x} & \hat{y} & \hat{z}\\ -1 & 2 & 1\\ 3 & 1 & -1\end{vmatrix} = \begin{pmatrix}-3\\2\\-7\end{pmatrix}\mathrm{Nm}$$ [3]

Problem 4 [10]

Potential energy $U_1 = qV(1,2,0) = 3\times10^{-3}\times(1^2+2\times1\times2+2-1\times0^2) = 21\times10^{-3}\,\text{J}$ [4]

Potential energy $U_2 = qV(0,3,1) = 3\times10^{-3}\times(0^2+2\times0\times3+3-0\times1^2) = 9\times10^{-3}\,\text{J}$ [4]

Change in potential energy $\Delta U = U_2 - U_1 = 9\times10^{-3} - 21\times10^{-3} = -12\times10^{-3}\,\text{J}$ [2]

Problem 5 [15]

Electric field $\vec{E} = -\nabla V = \begin{pmatrix} -\frac{\partial}{\partial x}240y \\ -\frac{\partial}{\partial y}240y \\ -\frac{\partial}{\partial z}240y \end{pmatrix} = \begin{pmatrix} 0 \\ -240 \\ 0 \end{pmatrix}\text{Vm}^{-1}$ [3]

The electric field is uniform, has a magnitude of 240 Vm^{-1} and points in the –ive y direction [2]

Change in potential energy
$\Delta U = q\big(V(0.3,0.3,0.1) - V(0.1,0.2,0.3)\big) = 7\times10^{-3}\times(240\times0.3 - 240\times0.2) = 0.168\,\text{J}$ [2]

Work done $W = q\vec{E}\cdot(\vec{r}_3 - \vec{r}_1)$ [2]

$$W = 7\times10^{-3}\begin{pmatrix} 0 \\ -240 \\ 0 \end{pmatrix}\cdot\left(\begin{pmatrix} 0.3 \\ 0.3 \\ 0.1 \end{pmatrix} - \begin{pmatrix} 0.1 \\ 0.2 \\ 0.3 \end{pmatrix}\right) = 7\times10^{-3}\begin{pmatrix} 0 \\ -240 \\ 0 \end{pmatrix}\cdot\begin{pmatrix} 0.2 \\ 0.1 \\ -0.2 \end{pmatrix} = -0.168\,\text{J}$$ [3]

Hence the work done appears as the change in potential energy of the system [1]

The work done is independent of the path taken, so the result must be the same despite the intermediate step [2]

The maximum total mark for this Tutorial is 50.