First Year Electricity & Magnetism **Classwork 3** **15 Feb 2008**

Numbers in italics refer to the Exercise number in the 12th Edition of Young & Freedman's "University Physics". Answers to odd-numbered questions are at the back of the book. Some useful formulae are given at the end of this sheet (see overleaf).

1. [*23.7*] A point charge $Q = +4.60\,\mu$C is held fixed at the origin. A second point charge $q = +1.20\,\mu$C with mass of 2.80×10^{-4} kg is placed on the x-axis, 0.250 m from the origin. a) What is the electric potential energy U of the pair of charges? (Take U to be zero when the charges have infinite separation.) b) The second point charge is released from rest. What is its speed when its distance from the origin is i) 0.500 m? ii) 5.00 m?

2. [*23.14*] Identical point charges $q = +5.00\,\mu$C are placed at opposite corners of a square. The length of each side of the square is 0.200 m. A point charge $q_0 = -2.00\,\mu$C is placed at one of the empty corners. How much work is done on q_0 by the electric force when q_0 is moved to the other empty corner?

3. [*23.32*] A total electric charge of 3.50 nC is distributed uniformly over the surface of a metal sphere with a radius of 24.0 cm. If the potential is zero at a point at infinity, find the value of the potential at the following distances from the centre of the sphere: a) 48.0 cm; b) 24.0 cm; c) 12.0 cm.

4. An electric dipole consisting of charges $\pm q$ of dipole moment $\mathbf{p} \equiv qd\hat{\mathbf{z}}$ is located at the origin. Given that the electric potential for $|\mathbf{r}| \gg d$ is given by

$$V \approx \frac{q\,d\,z}{4\pi\epsilon_0 r^3} \equiv \frac{\mathbf{p}\cdot\mathbf{r}}{4\pi\epsilon_0 r^3}$$

differentiate this expression with respect to x, y, and z to show that the electric field in this far-field limit is

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0}\left(\frac{3\,(\mathbf{p}\cdot\mathbf{r})\,\mathbf{r}}{r^5} - \frac{\mathbf{p}}{r^3}\right)$$

Remember ISEE: *Identify* the relevant concepts, including the target variable (what you need to find); *Set Up* the problem, usually with the help of a sketch; *Execute* the calculation needed to find the value of the target variable; finally *Evaluate* your answer: does it correspond to the symmetry of the problem, does the answer seem reasonable?

Some possibly useful information and formulae:

$$V = \frac{q}{4\pi\epsilon_0 r} \quad \text{for a point charge } q \text{ at the origin}$$

$$\mathbf{r} = x\hat{\mathbf{x}} + y\hat{\mathbf{y}} + z\hat{\mathbf{z}}$$

$$|\mathbf{r}| \equiv (\mathbf{r}\cdot\mathbf{r})^{1/2} = \left(x^2 + y^2 + z^2\right)^{1/2}$$

$$\mathbf{E} = -\frac{\partial V}{\partial x}\hat{\mathbf{x}} - \frac{\partial V}{\partial y}\hat{\mathbf{y}} - \frac{\partial V}{\partial z}\hat{\mathbf{z}}$$

Symbol	Value	Units
ϵ_0	8.85×10^{-12}	$C^2/N\,m^2$
$1/4\pi\epsilon_0$	8.99×10^{9}	$N\,m^2/C^2$

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