Term Test II: Wednesday February 3, 2016

Answer three out of the following four questions.
Each question carries equal marks. Show all working.
Allowed: 1 hour 50 mins. Calculator, formula sheets (given)

1a) Find the electric dipole moment of a cubical volume of charge that extends from $-a \le x, y, z \le a$ with $\rho(\vec{r}) = Ax^2$, where *A* is a constant.
b) Two small electric dipoles each composed of two point charges $\pm q$ and with dipole moments $\vec{p}_1 = p\,\hat{x}$ and $\vec{p}_2 = p\,\hat{y}$ respectively are centred at $\vec{r}_1 = \vec{0}$ and $\vec{r}_2 = a\,\hat{x}$. Sketch this configuration, and with careful reasoning explain and denote which direction is the net force on $\vec{p}_2$ (you don't need to calculate its magnitude).

2. Two 2.0 cm × 2.0 cm rectangular metal plates are held parallel to the floor, separated by a vertical distance of 1.0 mm.
a) What charge must be placed on each plate to create a uniform electric field of magnitude 2.0×10^6 N/C in the space between the plates?
b) Now assume that a dielectric slab with $\varepsilon_r = 3$ and the same area as the plates but of thickness $d \approx 1.0\,\text{mm}$ is slid between the plates. Find the surface charge density induced on the upper and lower faces of this slab. What is the change in the potential difference between the plates after the slab was introduced compared with before?

3. A spherical conductor of radius *a* carries a total charge Q. It is surrounded by a shell out to radius *b* $(b > a)$ of dielectric material of susceptibility χ_e. Find the total energy stored in this configuration.

4. Suppose $V(\vec{r}) = xy^2z^2$ volts in a region of space defined by $0 < x, y, z < 2$.
(a) Find the charge density $\rho(\vec{r})$ in this region, and also the total charge in this cube.
(b) If this charge density is traveling with a velocity of $100\,\hat{z}$ m/s, find the instantaneous current crossing the surface defined by $z = 1$; $0 < x, y < 2$.