SECTION B

7. (a) A charge Q is uniformly distributed on a circle of radius R and axis Oz, with the origin O at the centre of the ring.

   i. What is the magnitude of the electric field at the centre of the ring? [2]

   ii. Determine an approximate (nonzero) expression for the electric field at a point on the Oz axis for $z \gg R$. [3]

   iii. Determine the electric potential at each point P along the $z-$axis. [5]

   (b) A charge q is placed at each of the four corners $(\pm a, 0, 0)$, $(0, \pm a, 0)$ of a square. Show that the electric potential at a point (x, y, z) near the origin is of the form:

$$V \simeq \frac{q}{4\pi\epsilon_0 a}\left[4 + \frac{k_1 x^2 + k_2 y^2 + k_3 z^2}{a^2}\right]$$

   and determine the values of the constants k_1, k_2, k_3. [*Hint:* use the expansion $(1+\epsilon)^{-1/2} \simeq 1 - \frac{\epsilon}{2} + \frac{3}{8}\epsilon^2$, valid for $\epsilon << 1$.] [10]

8. (a) Derive the capacitance of a parallel-plate capacitor of area A and plate separation d. [5]

   (b) A charge Q is distributed uniformly over the surface of a spherical shell of radius R. Determine the magnitude and direction of the electric field

   i. inside the shell ($r < R$), and [2]

   ii. outside the shell ($r > R$). [3]

   (c) An isolated conducting sphere with radius R has a charge Q.

   i. Determine the potential energy stored in the electric field of this charged conductor. [5]

   ii. What is the energy density in the electric field at the surface of the sphere? [5]