Section Seven Electric Field

Part one

The human heart consists largely of elongated muscle cells, some 100 um long and 15 um in diameter. In its resting state, a cell contains two concentric layers of charge, which confine the electric field to the cell membrane (Fig. 7.1a). When the heart contracts, a wave of depolarization sweeps through, depleting charge and giving each cell a dipole moment (Fig. 7.2b). As a result, the entire organ acts like an electric dipole, producing an external field, which is indirectly detected by electrocardiography. Although the direction of the heart's dipole moment varies, Fig. 7.2c is typical. In answering the questions that follow, consider the heart in isolation—don't concern yourself with the effect of surrounding tissues on its electric field

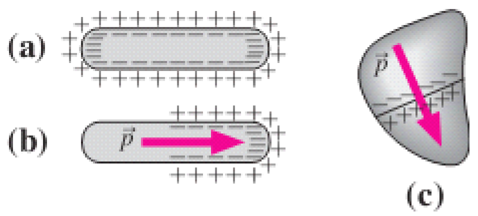


FIGURE 7.1 Heart cells (a) in the resting state and (b) partially depolarized, resulting in a dipole moment (c) Typical orientation of the heart's dipole moment vector. Cells along the line are depolarizing.

1. At a distance r, far from the heart, the heart's electric field

a. falls off as $1/r$

b. falls off as $1/r^2$

c. falls off as $1/r^3$

d. falls off as $1/r^4$

2. At a given distance, far from the heart compared with its size, the electric field

a. is weaker along an extension of the line shown in Fig. 7.1c than on a perpendicular line.

b. is stronger along a an extension of the line shown in Fig. 7.1c than on a perpendicular line.

c. has the same value at positions perpendicular and parallel to the line in Fig. 7.1 c.

3. The difference between Figs. 7.1a and 7.1 b that results in an external electric field in one case but not the other is that

a. there's no net charge in Fig. 7.1 a but there is a net charge in Fig. 7.1b.

b. the total charge is greater in Fig.7.1 a.

c. the charge is distributed in Fig. 7.1b so there's more negative charge to the left and more positive charge to the right.

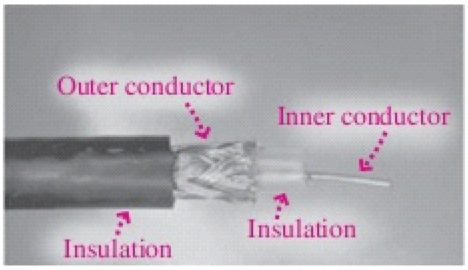
4. At the instant shown in Fig. 7.1 c , there's an electric field within the heart that points approximately

a. in the direction of the dipole moment vector

b. opposite the dipole moment vector

c. perpendicular to the dipole moment vector

Coaxial cables are widely used with audio-visual technology, electronic instrumentation, and radio broadcasting, because they minimize interference with or from signals traveling on the cable. Coaxial cables consist of a wire inner conductor surrounded by a thin cylindrical conducting shield, usually of braided copper (Fig. 21.36). Flexible insulation separates the conductors. A straight length of coaxial cable can be approximated as an infinitely long wire surrounded by a cylindrical shell. Normally the two conductors carry charges of equal magnitude but opposite sign. (Charge actually varies with time and position as signals travel down the cable, but for these problems consider the charge to be fixed and spread uniformly.)



5. For a coaxial cable in electrostatic equilibrium carrying equal but opposite charges on its two conductors, there's a nonzero electric field

a. only in the space between the wire and shield.

b. in the space between wire and shield, and outside the shield.

c. inside the metal conducting wire and shield, as well as between the wires and outside the shield.

d. only outside the shield.

6. A coaxial cable carries equal but opposite charges on its two conductors. In electrostatic equilibrium, charge on the shield

a. lies entirely on its outer surface.

b. is divided evenly between inner and outer surfaces.

c. lies entirely on its inner surface.

d. distributes itself differently depending on the magnitude of the charge.

7. How does the electric field between the conductors in a coaxial cable in electrostatic equilibrium depend on the radial distance r from the cable's axis?

a. it's constant

b. as $1/r$

c. as $1/r^2$

d. as $1/r^3$

8. A coaxial cable in electrostatic equilibrium carries charge on its inner conductor and on its shield. If the charge on the shield only is doubled,

a. the magnitude of the electric field between the conductors will double.

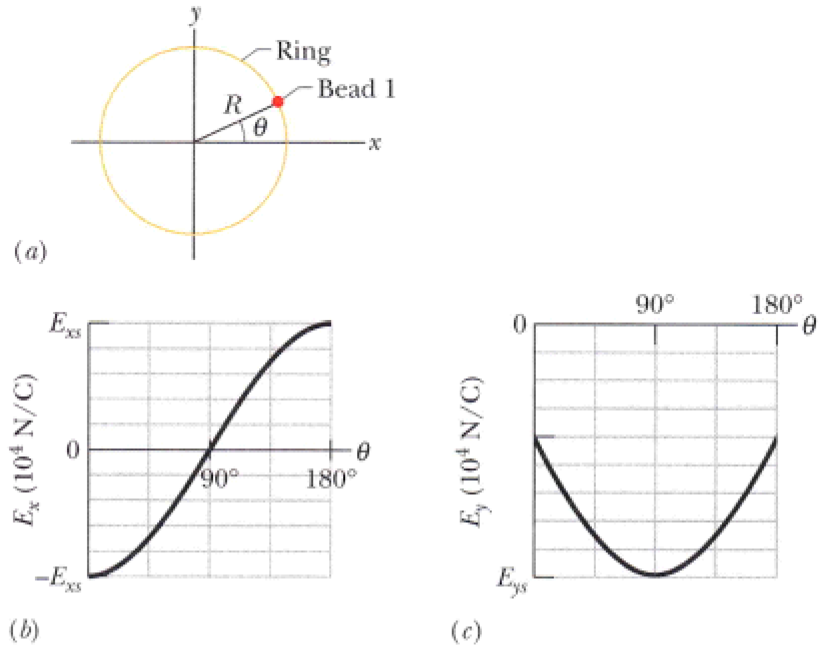
b. the magnitude of the electric field outside the shield will double.

c. the magnitude of the electric field at the outer surface of the shield will become twice the magnitude of the field at the shield's inner surface.

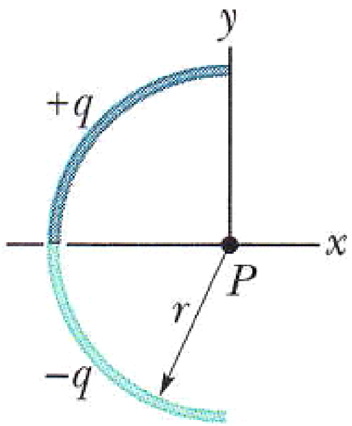
d. the magnitude of the electric field at the outer surface of the shield will equal the magnitude of the field at the shield's inner surface.

Part II

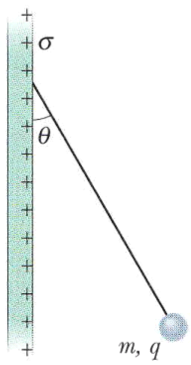
1 Two charged beads are on the plastic ring in Fig. 7.3a. Bead 2, which is not shown, is fixed in place on the ring, which has radius R =60.0 cm. Bead 1 is initially on the x axis at angle θ=0° , It is then moved to the opposite side, at angle θ =180° , through the first and second quadrants of the xy coordinate system. Figure 7.3b gives the x component of the net electric field produced at the origin by the two beads as a function of 0,and Fig. 7.3c gives the y component. The vertical axis scales are set by Exs=5.0 X 10^4 N/C and Eys=-9.0 x 10^4 N/C. (a) At what angle θ is bead 2 located? What are the charges of (b) bead 1 and (c)bead 2?



2 In Fig. 7.4,a thin glass rod forms a semicircle of radius r =5.00 cm. Charge is uniformly distributed along the rod , wtth +q=4.50 pC in the upper half and -q - -4.50pC in the lower half. What are the (a) magnitude and (b) direction (relative to the positive direction of the x axis) of the electric field E at P, the center of the semicircle?



3 In Fig. 7.5, a small, non-conducting ball of mass m: 1.0 mg and charge q =2.0x 10^{-8} C (distributed uniformly through its volume) hangs from an insulating thread that makes an angle θ= 30 ° with a vertical, uniformly charged non-conducting sheet (shown in cross section). Considering the gravitational force on the ball and assuming the sheet extends far vertically and into and out of the page, calculate the surface charge density s of the sheet.



4. A charge distribution that is spherically symmetric but not uniform radially produces an electric field of magnitude $E=Kr^4$, directed radically outward from the center of the sphere. Here r is the radial distance from that center, and K is a constant. What is the volume density p of the charge distribution?