Summary

The **electric potential** V at any point in space is defined as the electric potential energy per unit charge:

$$V_{\mathrm{a}} = \frac{\mathrm{PE}_{\mathrm{a}}}{q}. \qquad \textbf{(17–2a)}$$

The **electric potential difference** between any two points is defined as the work done to move a 1 C electric charge between the two points. Potential difference is measured in volts (1 V = 1 J/C) and is sometimes referred to as **voltage**.

The change in potential energy when a charge q moves through a potential difference V_{ba} is

$$\Delta\mathrm{PE} = qV_{\mathrm{ba}}. \qquad \textbf{(17–3)}$$

The potential difference V_{ba} between two points a and b where a uniform electric field E exists is given by

$$V_{\mathrm{ba}} = -Ed, \qquad \textbf{(17–4a)}$$

where d is the distance between the two points.

An **equipotential line** or **surface** is all at the same potential, and is perpendicular to the electric field at all points.

The electric potential at a position P due to a single point charge Q, relative to zero potential at infinity, is given by

$$V = \frac{kQ}{r}, \qquad \textbf{(17–5)}$$

where r is the distance from Q to the position P.

[*The potential due to an **electric dipole** drops off as $1/r^2$. The **dipole moment** is $p = Ql$, where l is the distance between the two equal but opposite charges of magnitude Q.]

A **capacitor** is a device used to store charge (and electric energy), and consists of two nontouching conductors. The two conductors can hold equal and opposite charges, of magnitude Q, and the ratio of this charge to the potential difference V between the conductors is called the **capacitance**, C:

$$C = \frac{Q}{V}, \quad \text{or} \quad Q = CV. \qquad \textbf{(17–7)}$$

The capacitance of a parallel-plate capacitor is proportional to the area of each plate and inversely proportional to their separation:

$$C = \epsilon_0 \frac{A}{d}. \qquad \textbf{(17–8)}$$

The space between the two conductors of a capacitor contains a nonconducting material such as air, paper, or plastic; these materials are referred to as **dielectrics**, and the capacitance is proportional to a property of dielectrics called the **dielectric constant**, K (nearly equal to 1 for air).

A charged capacitor stores an amount of electric energy given by

$$\mathrm{PE} = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \tfrac{1}{2}\frac{Q^2}{C}. \qquad \textbf{(17–10)}$$

This energy can be thought of as stored in the electric field between the plates.

The energy stored in any electric field E has a density (energy per unit volume) of

$$\frac{\mathrm{PE}}{\text{volume}} = \tfrac{1}{2}\epsilon_0 E^2. \qquad \textbf{(17–11)}$$

[*Television and computer monitors traditionally use a **cathode ray tube** (CRT) that accelerates electrons by high voltage, and sweeps them across the screen in a regular way using deflection plates.]

[*An **electrocardiogram** (EKG or ECG) records the millivolt potential changes of each heart beat as the cells depolarize and repolarize, and displays these changes on a monitor screen or chart recorder printout.]

Questions

1. If two points are at the same potential, does this mean that no work is done in moving a test charge from one point to the other? Does this imply that no force need be exerted? Explain.
2. If a negative charge is initially at rest in an electric field, will it move toward a region of higher potential or lower potential? What about a positive charge? How does the potential energy of the charge change in each instance?
3. State clearly the difference (*a*) between electric potential and electric field, (*b*) between electric potential and electric potential energy.
4. An electron is accelerated by a potential difference of, say, 0.10 V. How much greater would its final speed be if it is accelerated with four times as much voltage? Explain.
5. Is there a point along the line joining two equal positive charges where the electric field is zero? Where the electric potential is zero? Explain.
6. Can a particle ever move from a region of low electric potential to one of high potential and yet have its electric potential energy decrease? Explain.
7. Compare the kinetic energy gained by a proton ($q = +e$) to the energy gained by an alpha particle ($q = +2e$) accelerated by the same voltage V.
8. If $V = 0$ at a point in space, must $\vec{\mathbf{E}} = 0$ there? If $\vec{\mathbf{E}} = 0$ at some point, must $V = 0$ at that point? Explain. Give examples for each.
9. Can two equipotential lines cross? Explain.
10. Draw in a few equipotential lines in Fig. 16–31b.

* 11. What can you say about the electric field in a region of space that has the same potential throughout?

12. A satellite orbits the Earth along a gravitational equipotential line. What shape must the orbit be?
13. When dealing with practical devices, we often take the ground (the Earth) to be 0 V. If, instead, we said the ground was −10 V, how would this affect (*a*) the potential V, and (*b*) the electric field E, at other points?
14. When a battery is connected to a capacitor, why do the two plates acquire charges of the same magnitude? Will this be true if the two conductors are different sizes or shapes?
15. We have seen that the capacitance C depends on the size, shape, and position of the two conductors, as well as on the dielectric constant K. What then did we mean when we said that C is a constant in Eq. 17–7?