Chapter 23

Electric Potential

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Lectures by Wayne Anderson

Goals for Chapter 23

- To calculate the electric potential energy of a group of charges
- To know the significance of electric potential
- To calculate the electric potential due to a collection of charges
- To use equipotential surfaces to understand electric potential
- To calculate the electric field using the electric potential

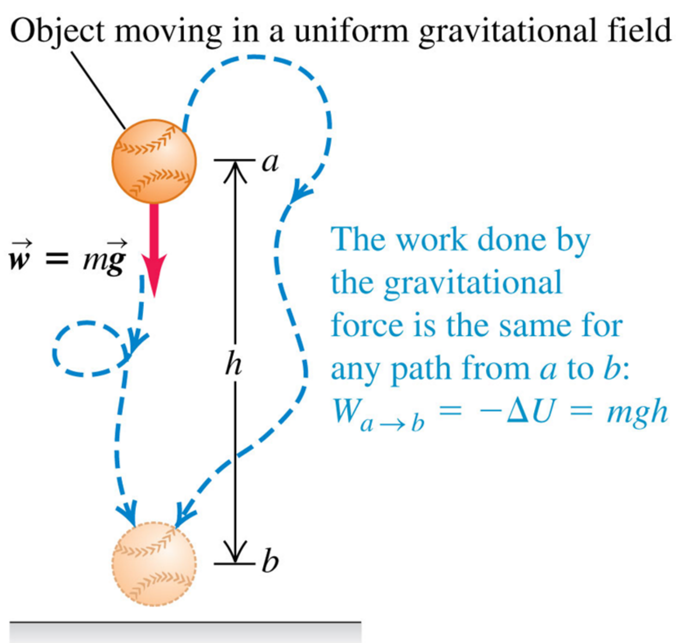
Introduction

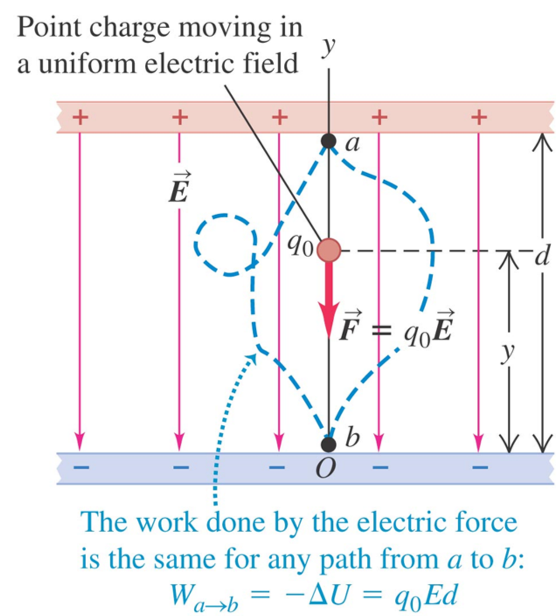
- How is electric potential related to welding?
- Electric potential energy is an integral part of our technological society.
- What is the difference between electric potential and electric potential energy?
- How is electric potential energy related to charge and the electric field?

Electric potential energy in a uniform field

- The behavior of a point charge in a uniform electric field is analogous to the motion of a baseball in a uniform gravitational field.

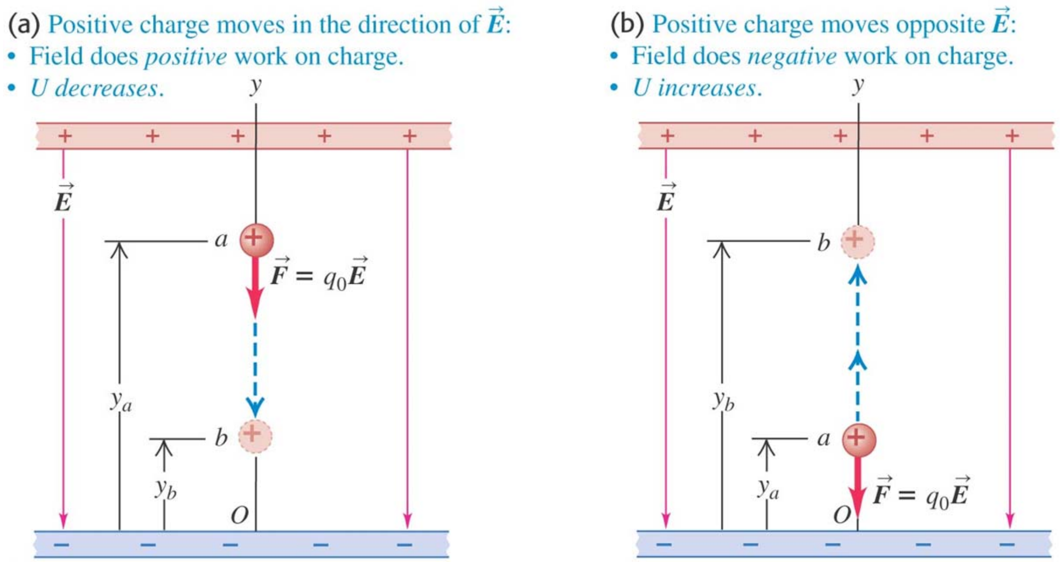
- Figures 23.1 and 23.2 below illustrate this point.





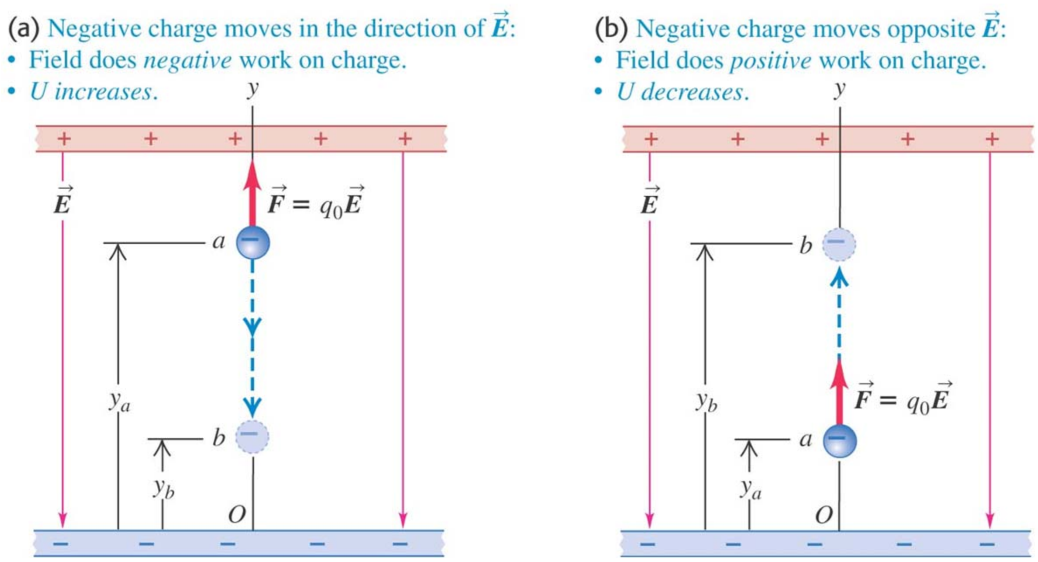
A positive charge moving in a uniform field

- If the positive charge moves in the direction of the field, the potential energy *decreases*, but if the charge moves opposite the field, the potential energy *increases*.
- Figure 23.3 below illustrates this point.



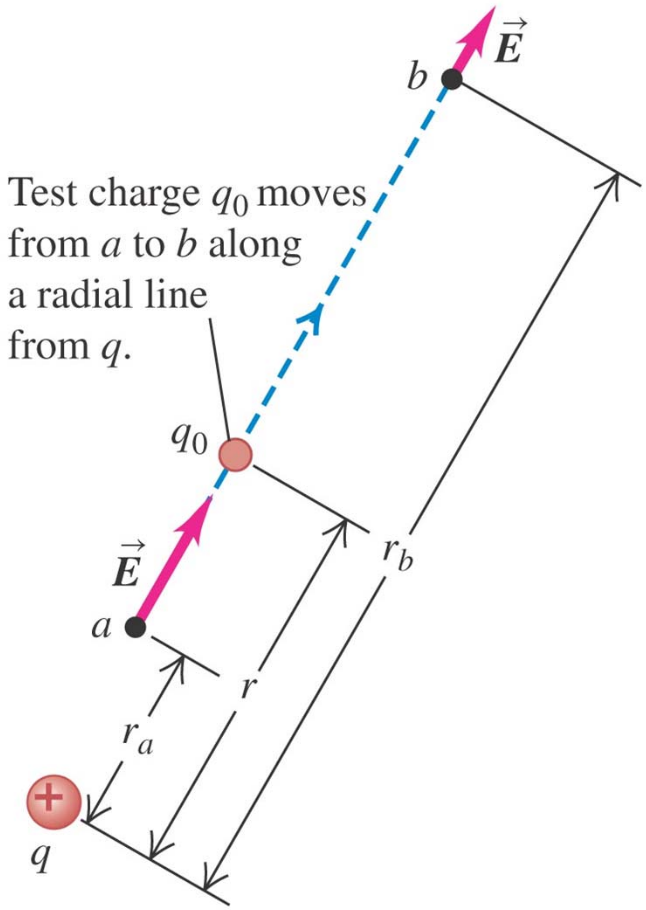
A negative charge moving in a uniform field

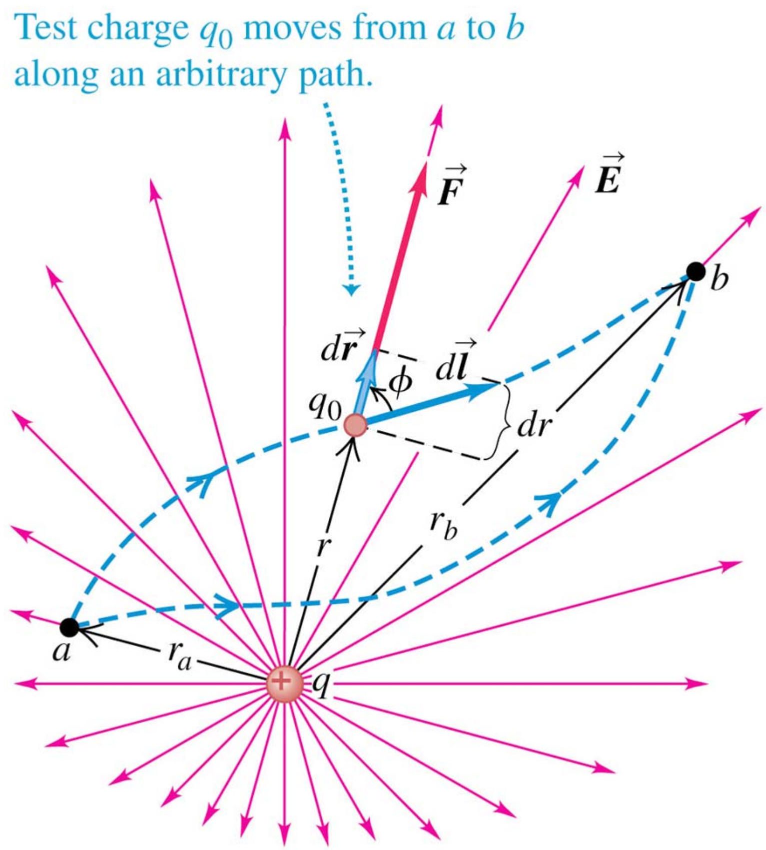
- If the negative charge moves in the direction of the field, the potential energy *increases*, but if the charge moves opposite the field, the potential energy *decreases*.
- Figure 23.4 below illustrates this point.



Electric potential energy of two point charges

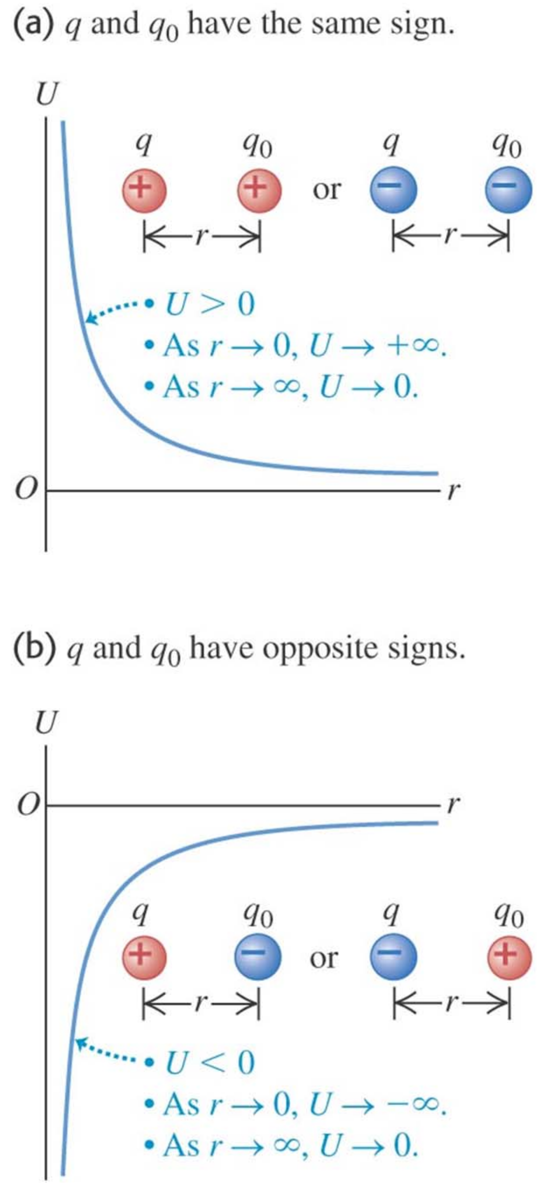
- Follow the discussion of the motion of a test charge q_0 in the text.
- The electric potential is the same whether q_0 moves in a radial line (left figure) or along an arbitrary path (right figure).





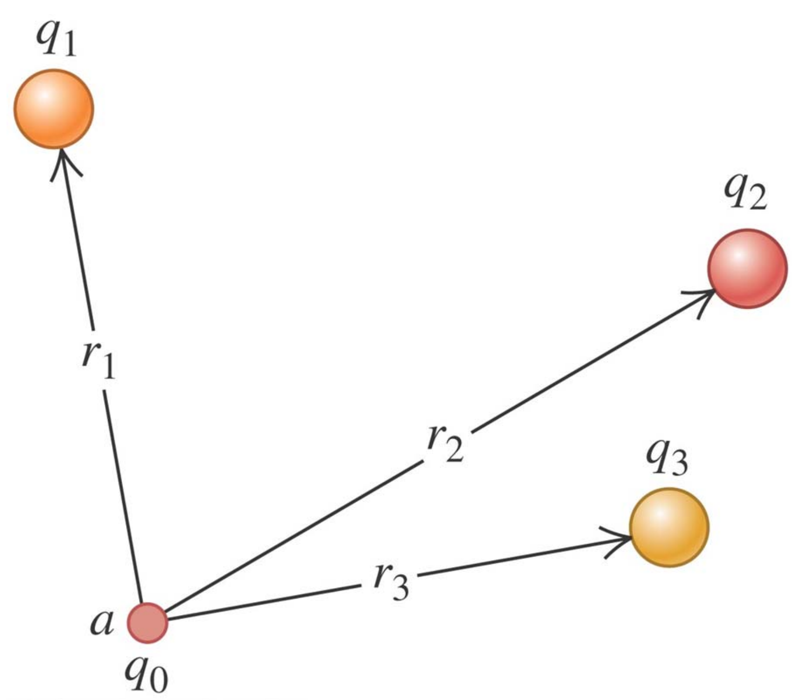
Graphs of the potential energy

- The sign of the potential energy depends on the signs of the two charges.
- See Figure 23.7 at the right.
- Follow Example 23.1.



Electrical potential with several point charges

- The potential energy associated with q_0 depends on the other charges and their distances from q_0, as shown in Figure 23.8 at the right.
- Follow the derivation in the text of the formula for the total potential energy U.
- Follow Example 23.2.

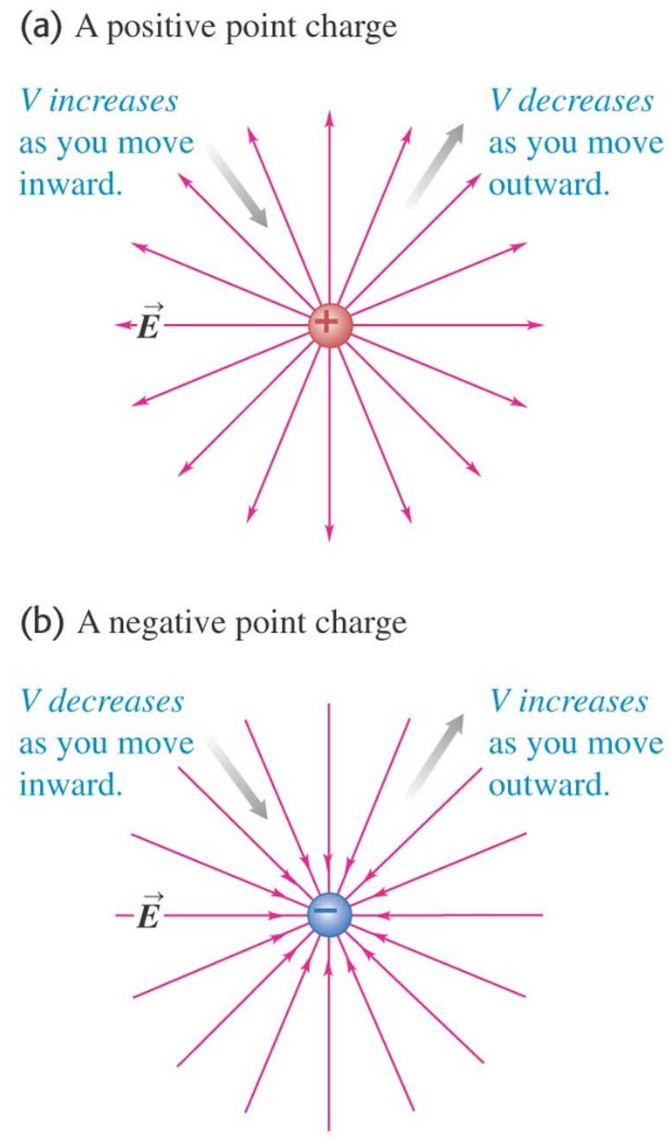


Electric potential

- *Potential* is *potential energy per unit charge*.
- We can think of the potential difference between points *a* and *b* in either of two ways. The potential of *a* with respect to *b* ($V_{ab} = V_a - V_b$) equals:
  - ✓ the work done by the electric force when a *unit* charge moves from *a* to *b*.
  - ✓ the work that must be done to move a *unit* charge slowly from *b* to *a* against the electric force.
- Follow the discussion in the text of how to calculate electric potential.

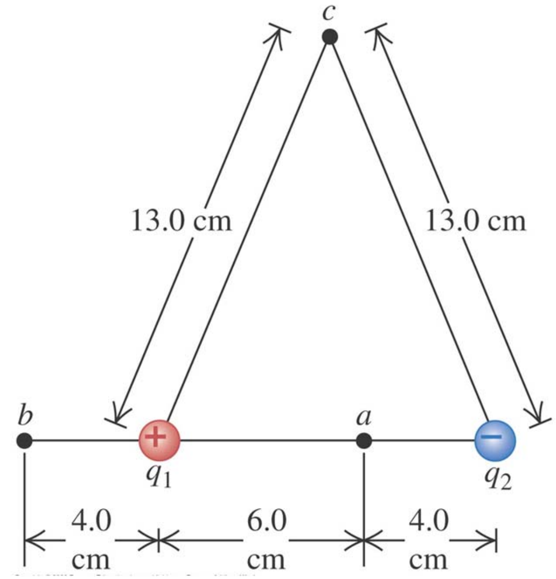
Finding electric potential from the electric field

- If you move in the direction of the electric field, the electric potential *decreases*, but if you move opposite the field, the potential *increases*. (See Figure 23.12 at the right.)
- Follow the discussion in the text.
- Follow Example 23.3.



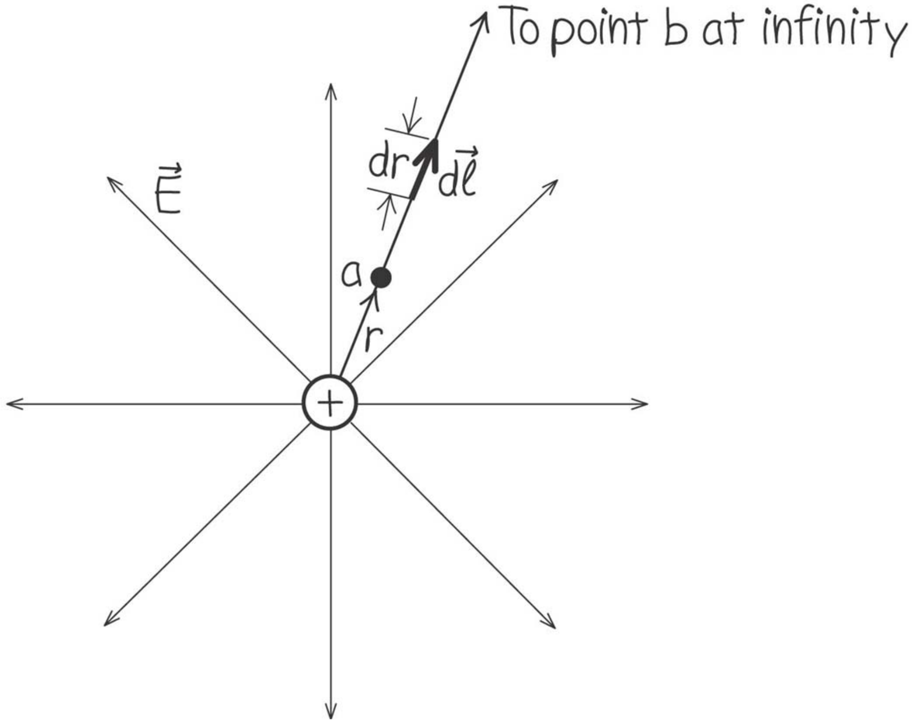
Potential due to two point charges

- Follow Example 23.4 using Figure 23.13 at the right.
- Follow Example 23.5.



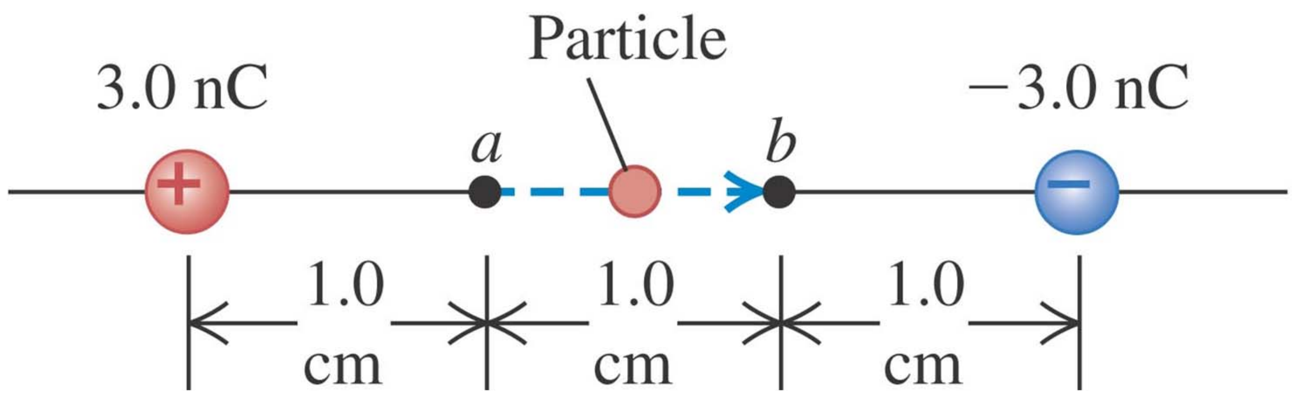
Finding potential by integration

- Example 23.6 shows how to find the potential by integration. Follow this example using Figure 23.14 at the right.



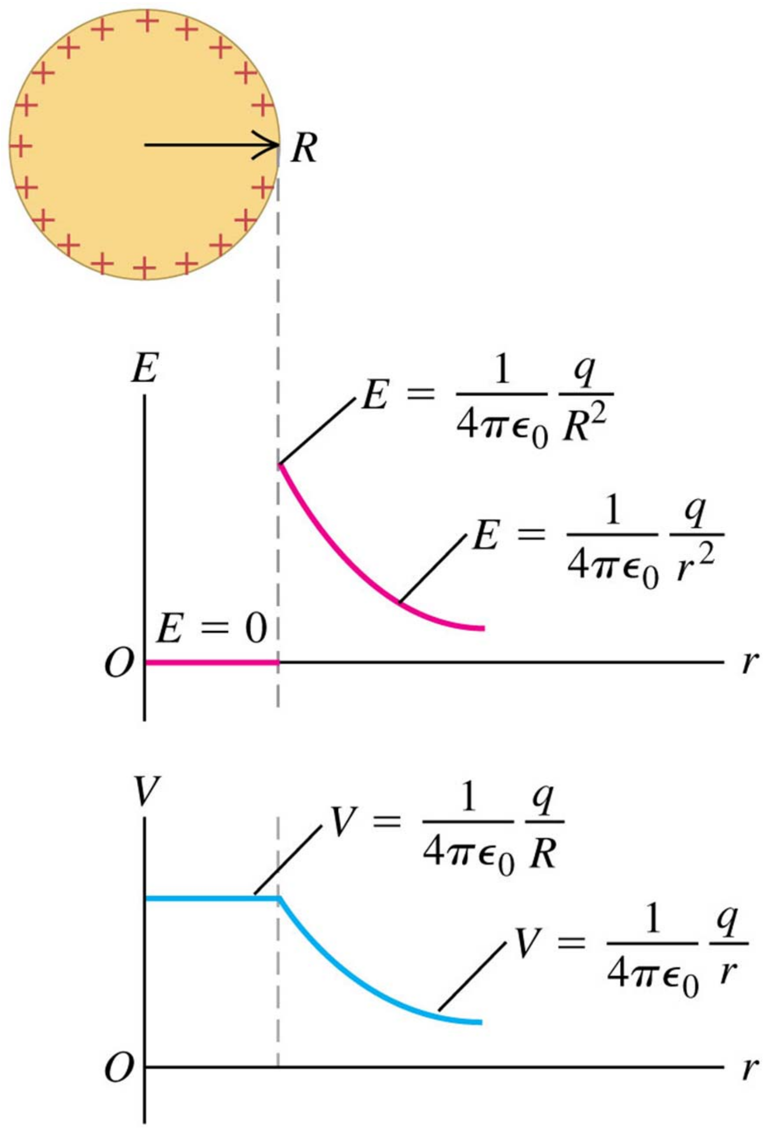
Moving through a potential difference

- Example 23.7 combines electric potential with energy conservation. Follow this example using Figure 23.15 below.



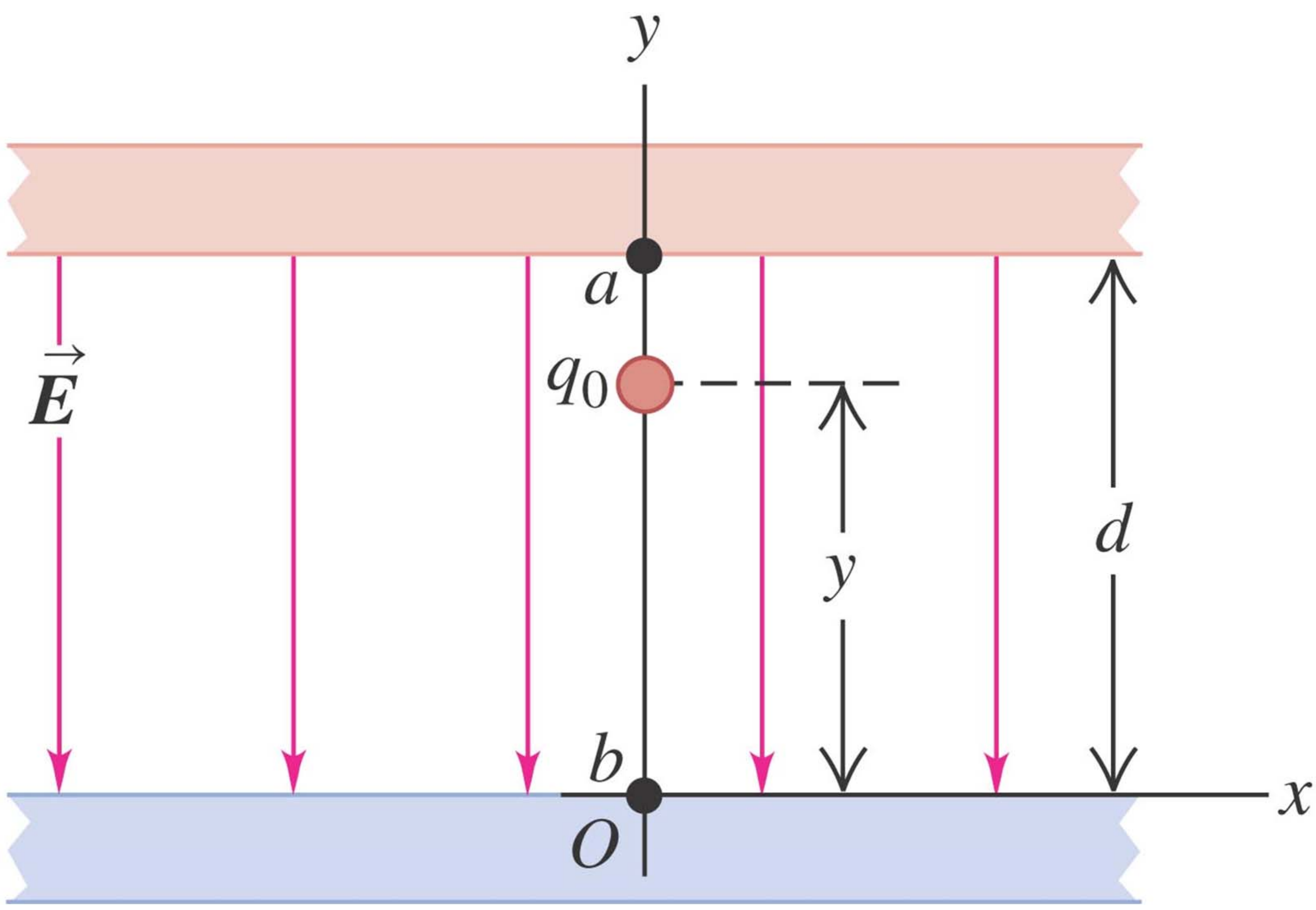
Calculating electric potential

- Read Problem-Solving Strategy 23.1.
- Follow Example 23.8 (a charged conducting sphere) using Figure 23.16 at the right.



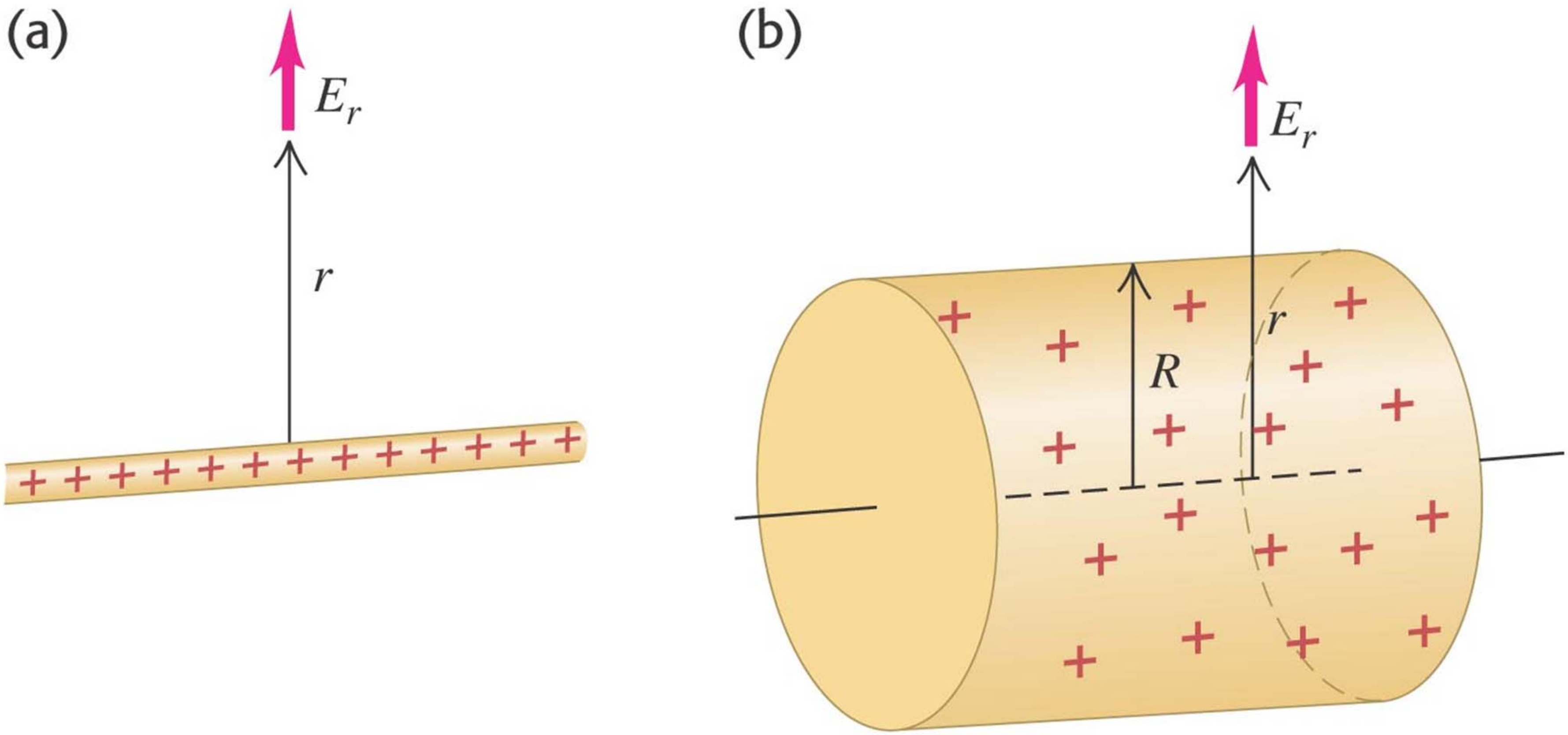
Oppositely charged parallel plates

- Follow Example 23.9 using Figure 23.18 below.



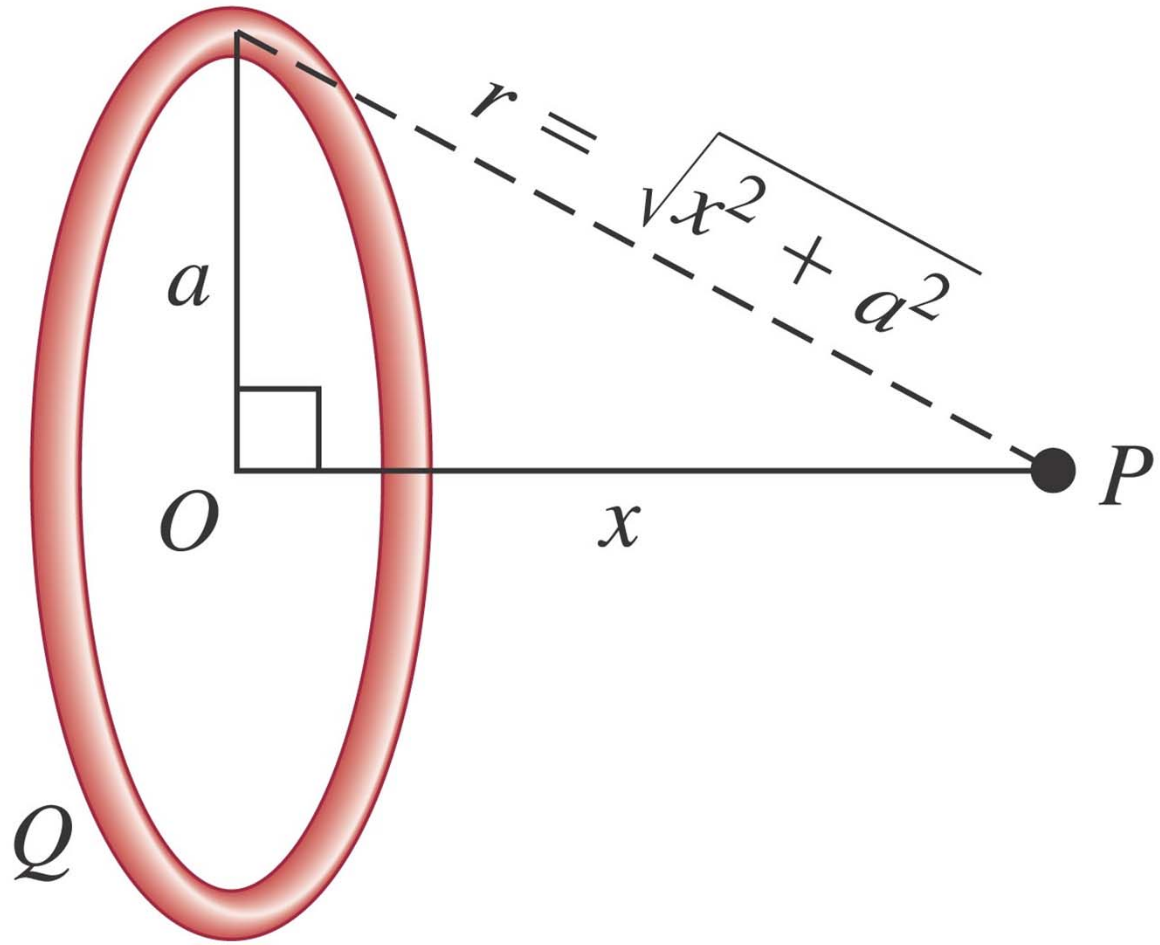
An infinite line charge or conducting cylinder

- Follow Example 23.10 using Figure 23.19 below.



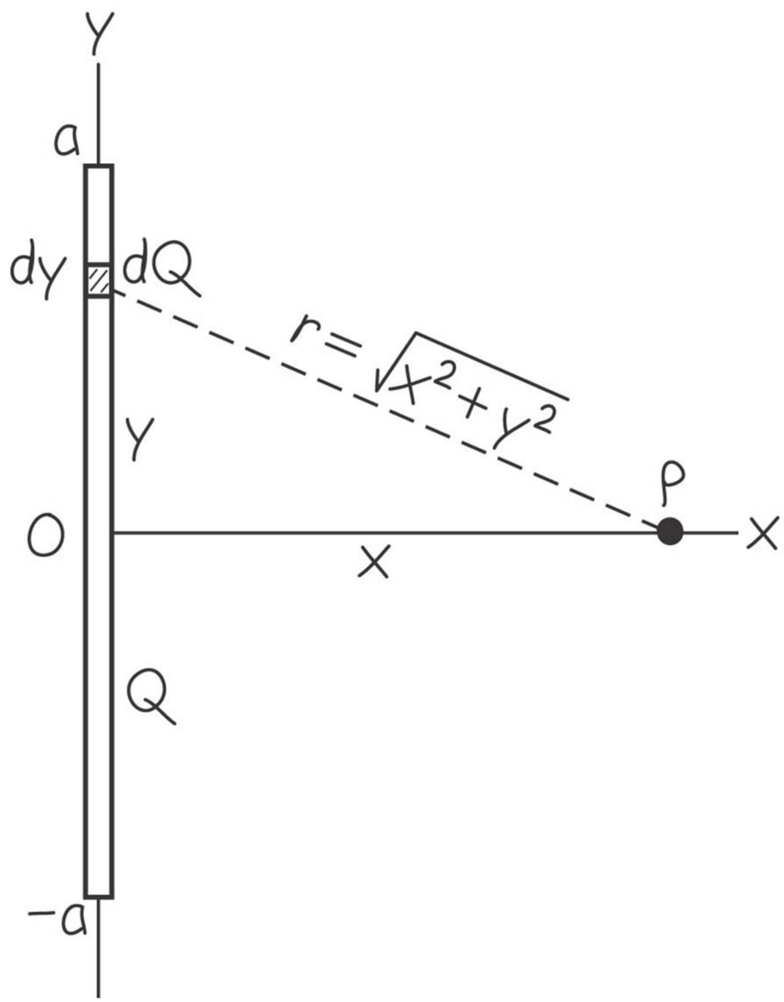
A ring of charge

- Follow Example 23.11 using Figure 23.20 below.



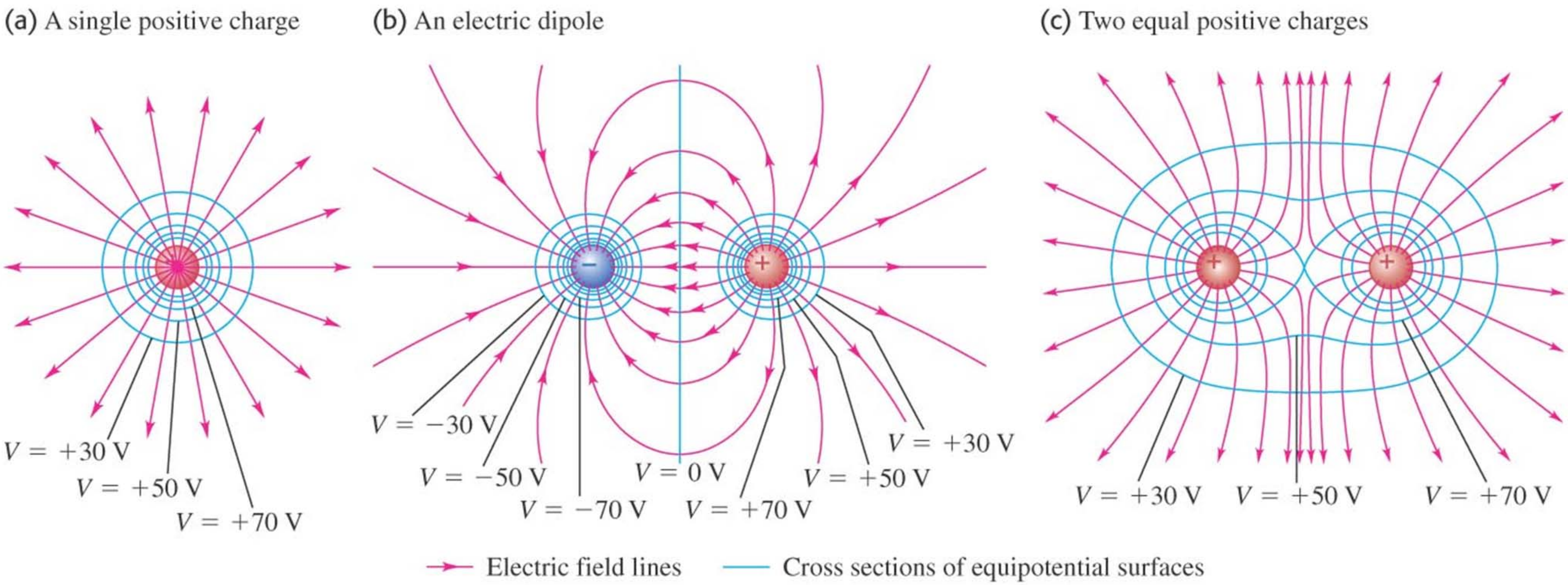
A finite line of charge

- Follow Example 23.12 using Figure 23.21 below.



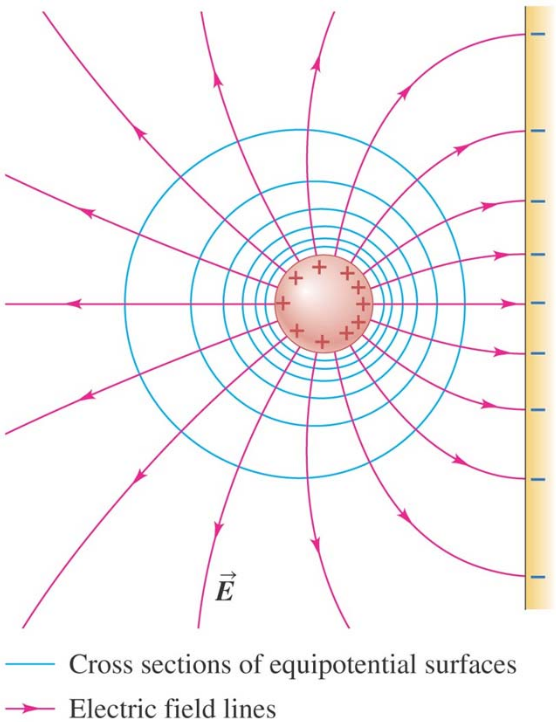
Equipotential surfaces and field lines

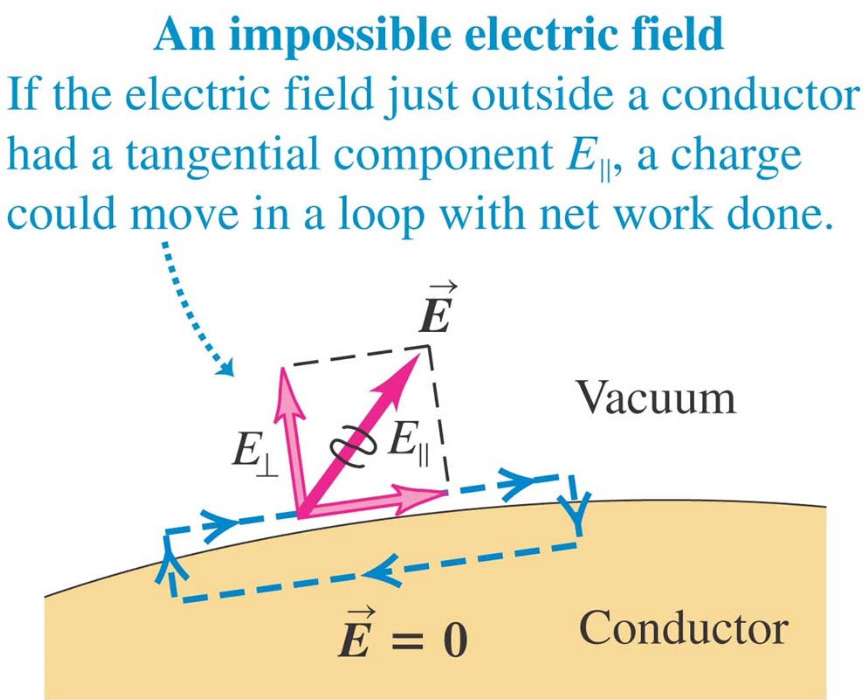
- An *equipotential surface* is a surface on which the electric potential is the same at every point.
- Figure 23.23 below shows the equipotential surfaces and electric field lines for assemblies of point charges.
- Field lines and equipotential surfaces are always mutually perpendicular.



Equipotentials and conductors

- When all charges are at rest:
  - ✓ the surface of a conductor is always an equipotential surface.
  - ✓ the electric field just outside a conductor is always perpendicular to the surface (see figures below).
  - ✓ the entire solid volume of a conductor is at the same potential.





Potential gradient

- Read in the text the discussion of *potential gradient*.
- Follow Example 23.13 which looks at a point charge.
- Follow Example 23.14 which deals with a ring of charge.