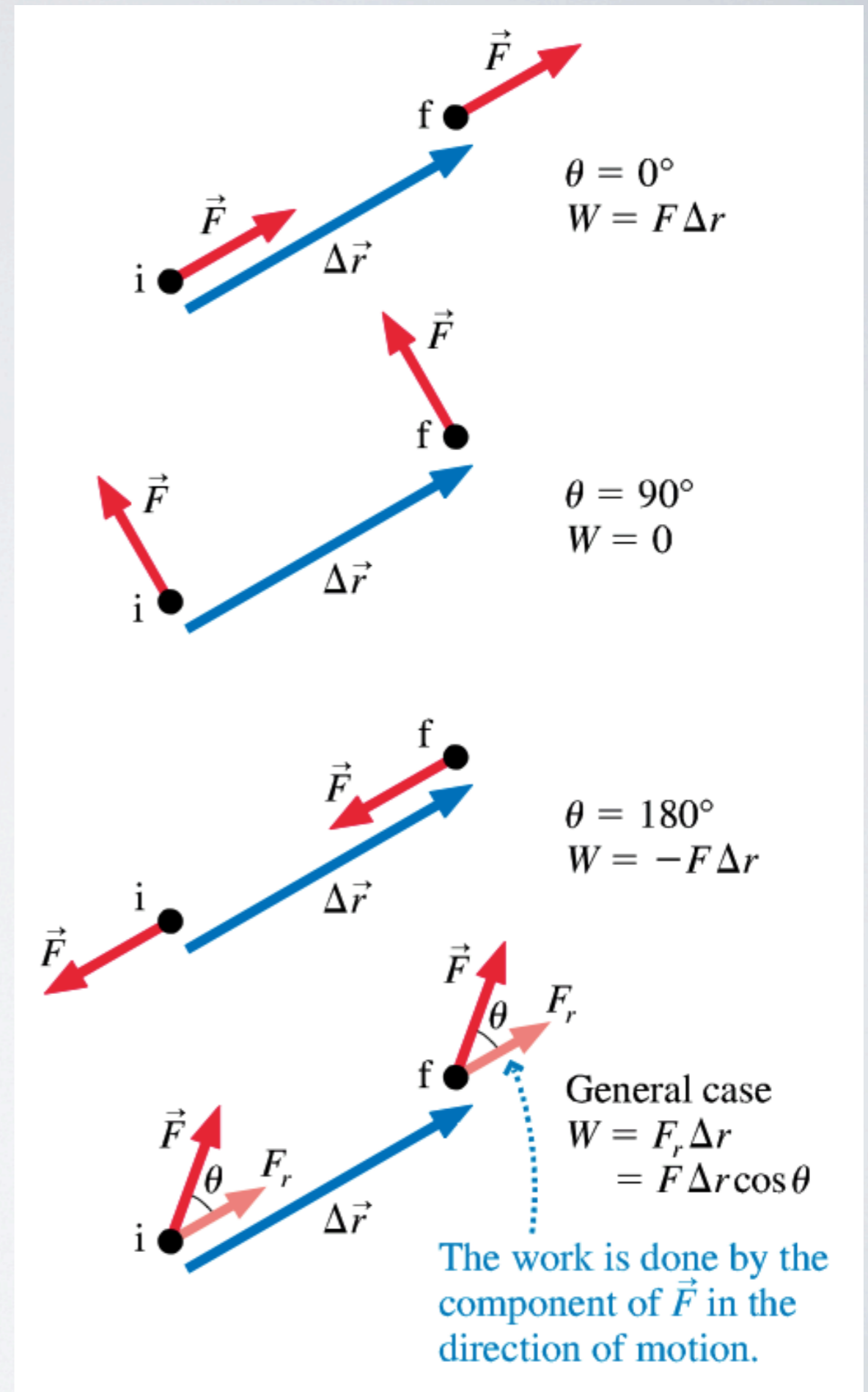
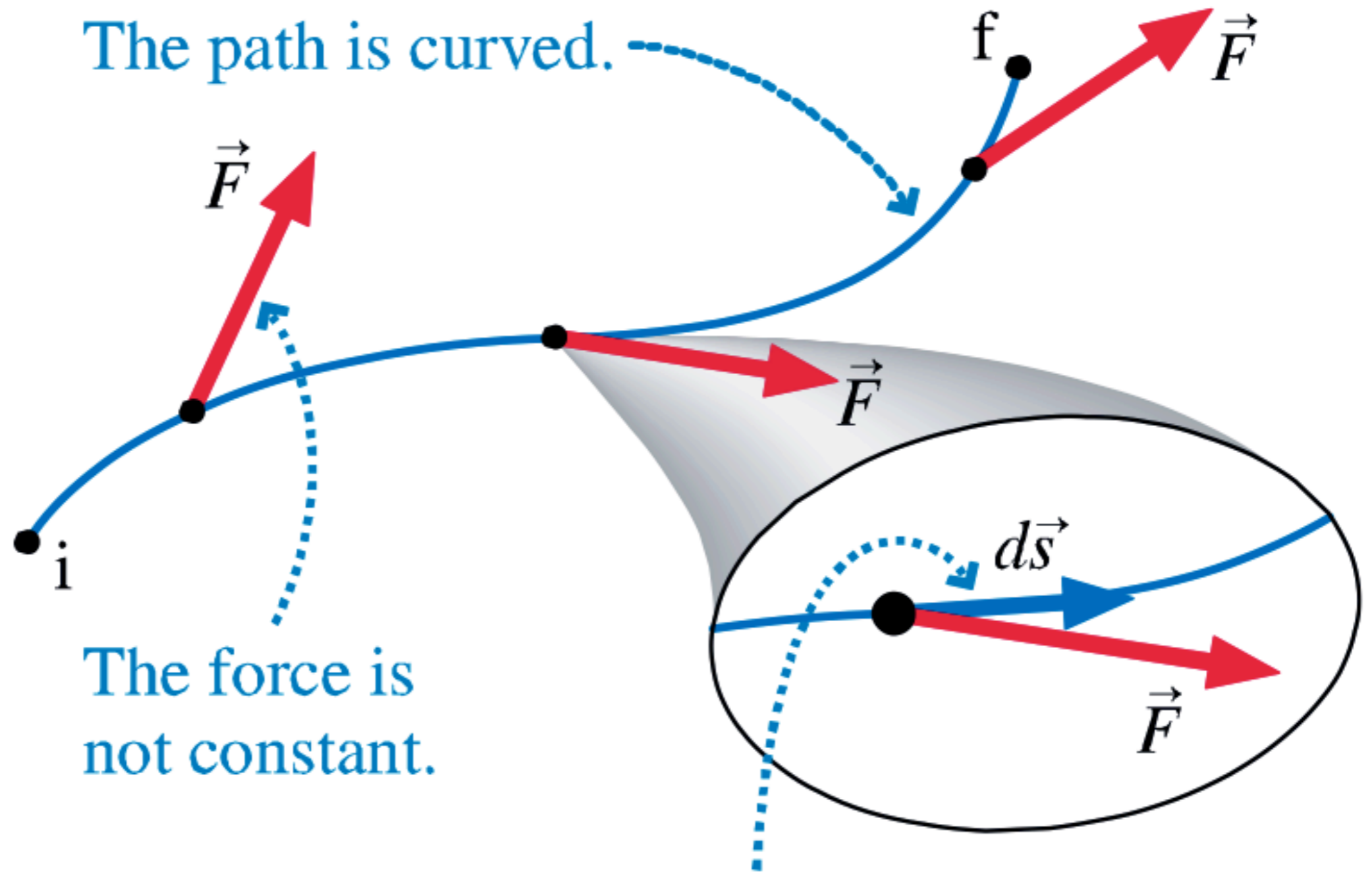


ELECTRIC POTENTIAL

The work done by a constant force



The work done along a curved path or by a variable force.

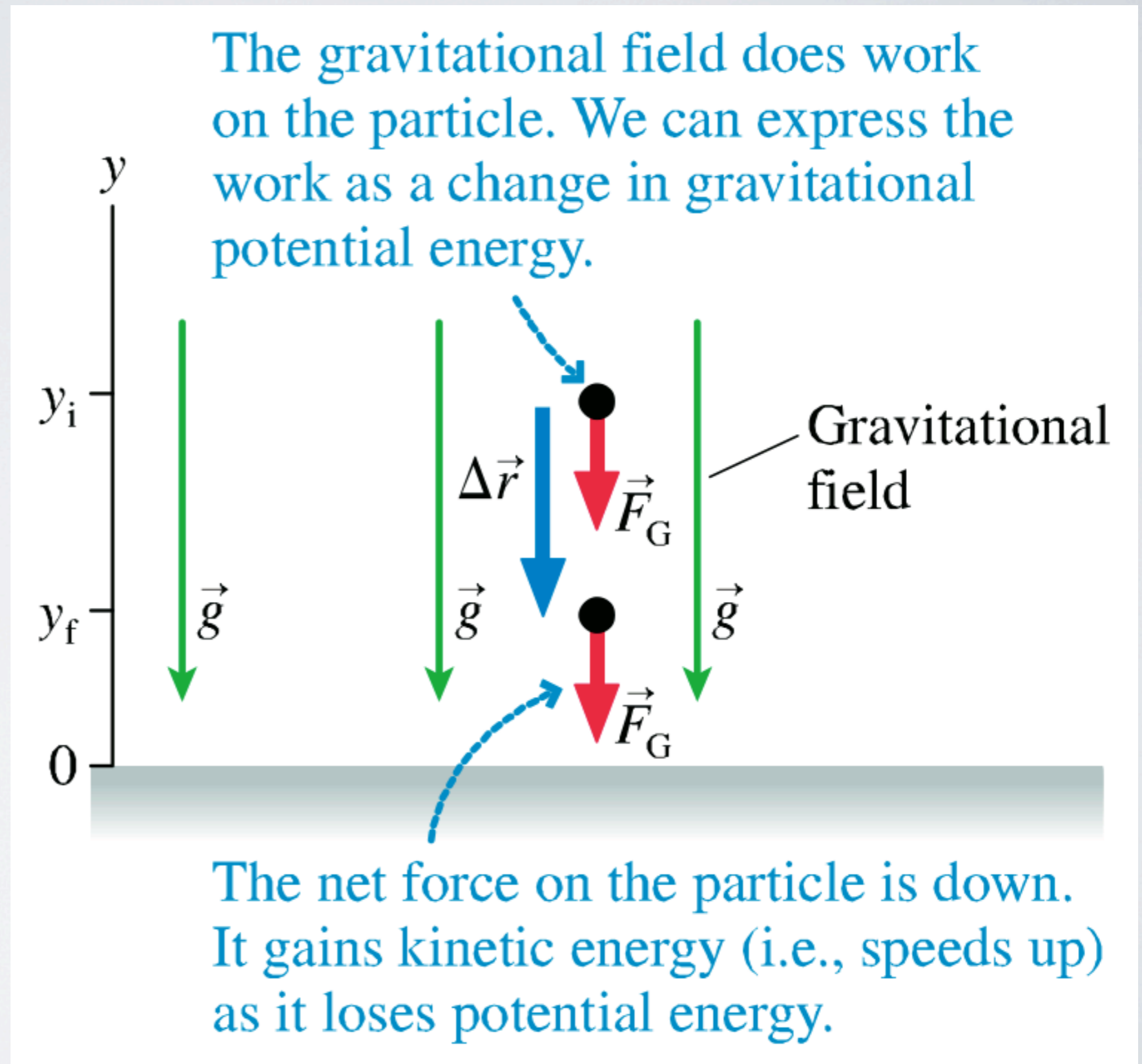


The path is curved.

The force is not constant.

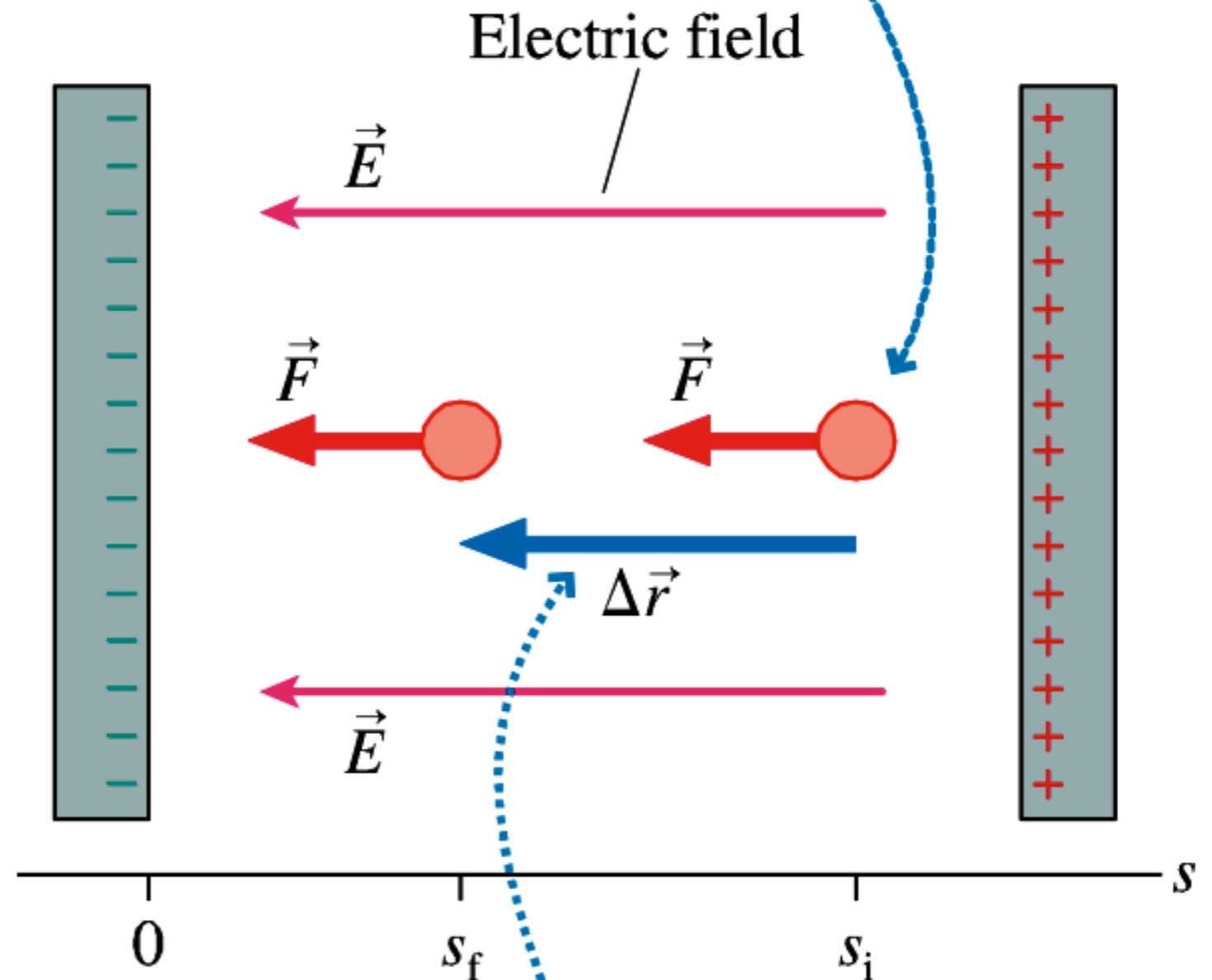
The work done in this small segment of the motion is $F_s ds = \vec{F} \cdot d\vec{s}$.

Potential energy is transformed into kinetic energy as a particle moves in a gravitational field.



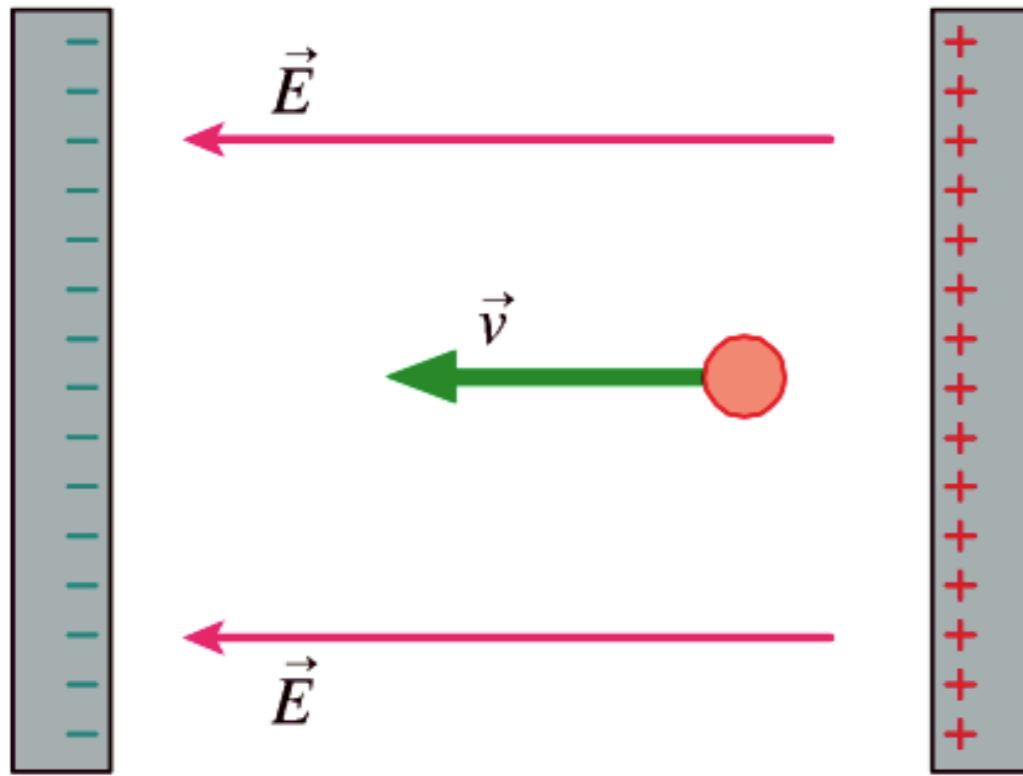
The electric field does work on the charged particle.

The electric field does work on the particle. We can express the work as a change in electric potential energy.

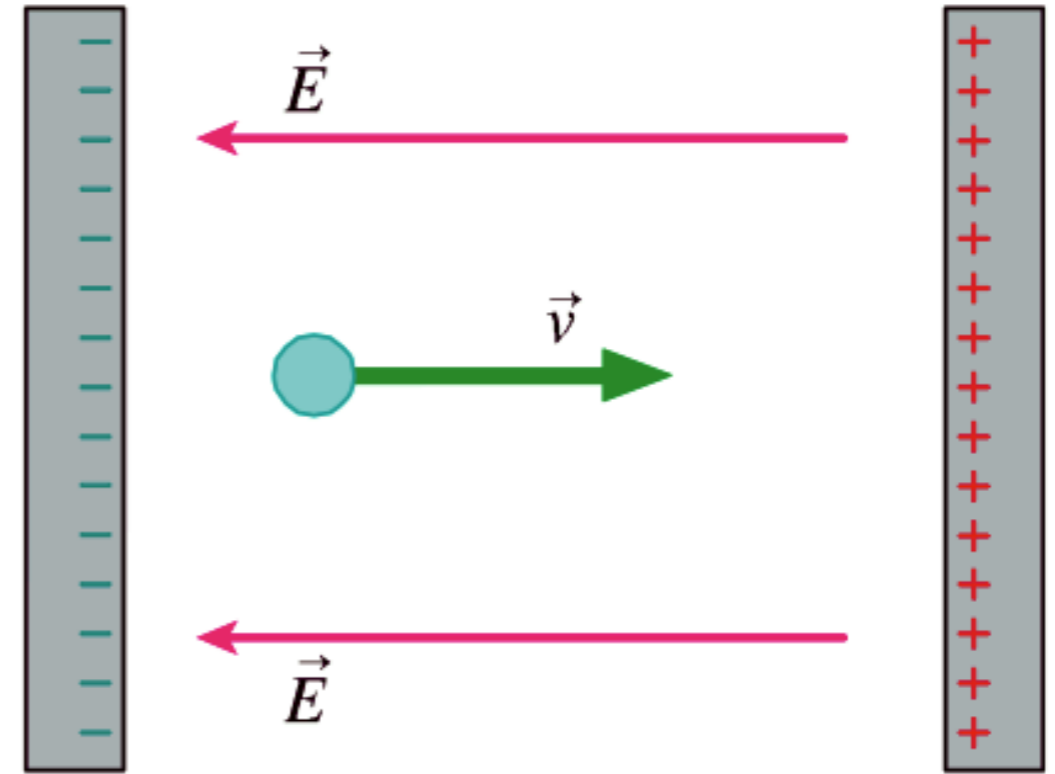


The particle is “falling” in the direction of \vec{E} .

A charged particle of either sign gains kinetic energy as it moves in the direction of decreasing potential energy.

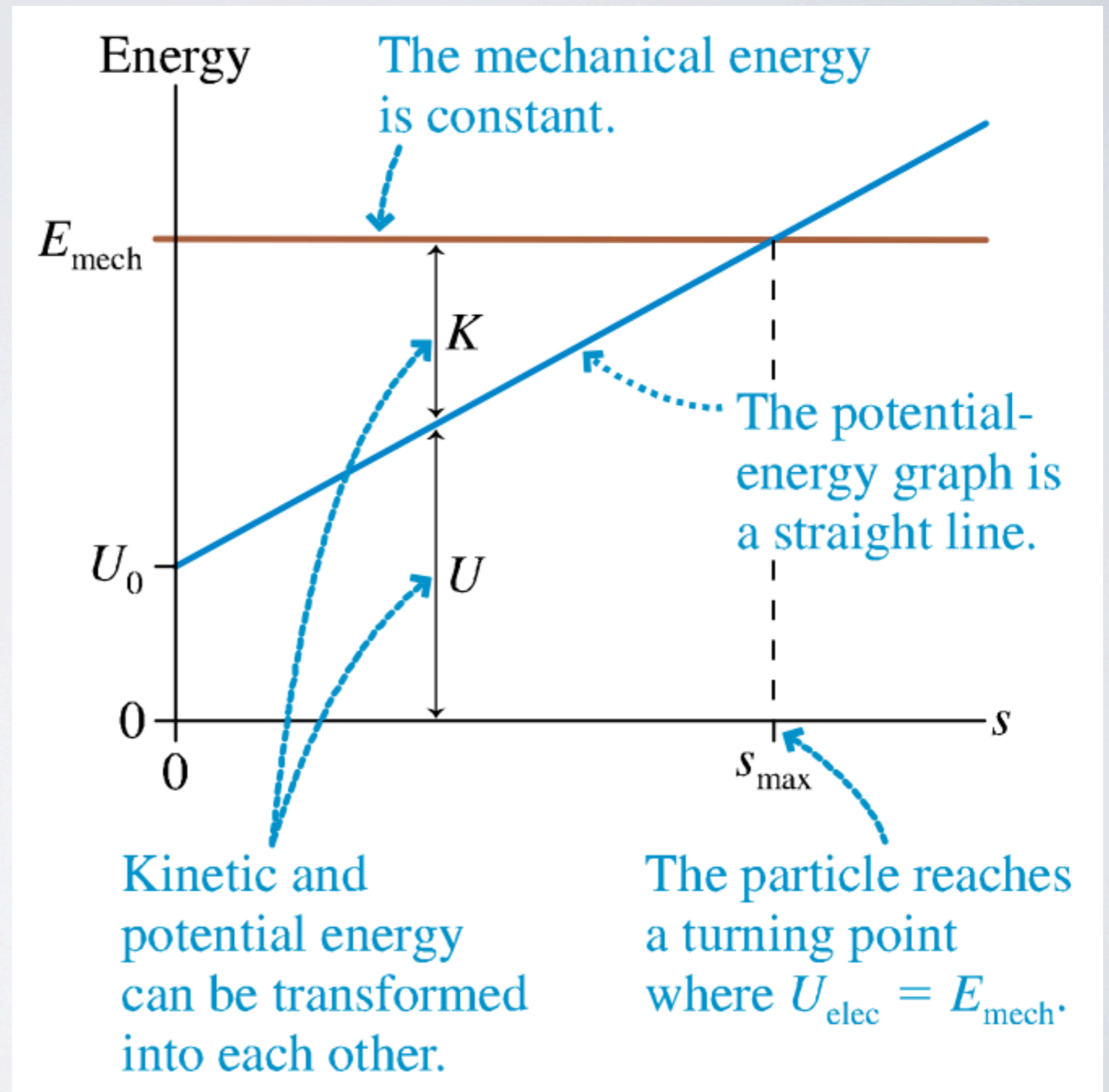


The potential energy of a positive charge decreases in the direction of \vec{E} . The charge gains kinetic energy as it moves toward the negative plate.



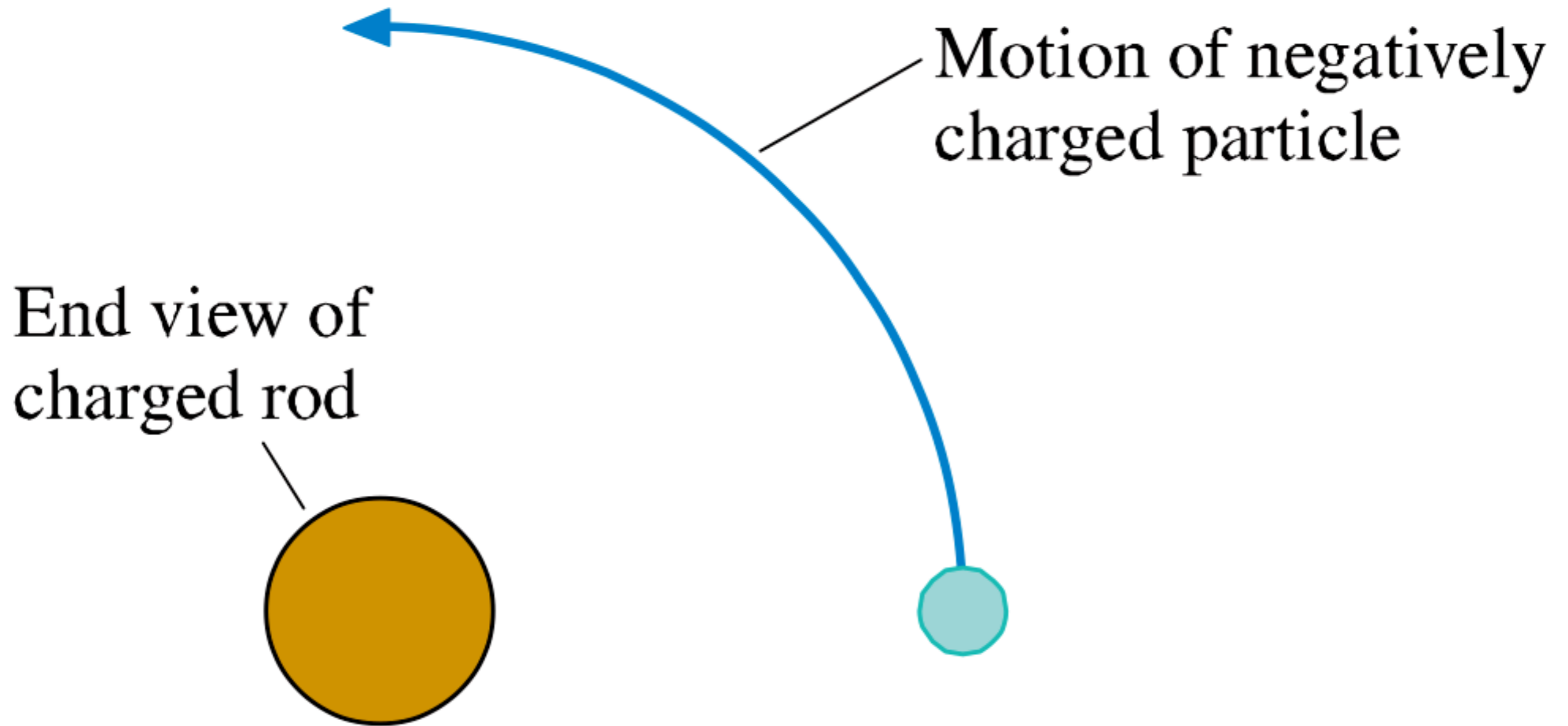
The potential energy of a negative charge decreases in the direction opposite to \vec{E} . The charge gains kinetic energy as it moves away from the negative plate.

The energy diagram for a positively charged particle in a uniform electric field.

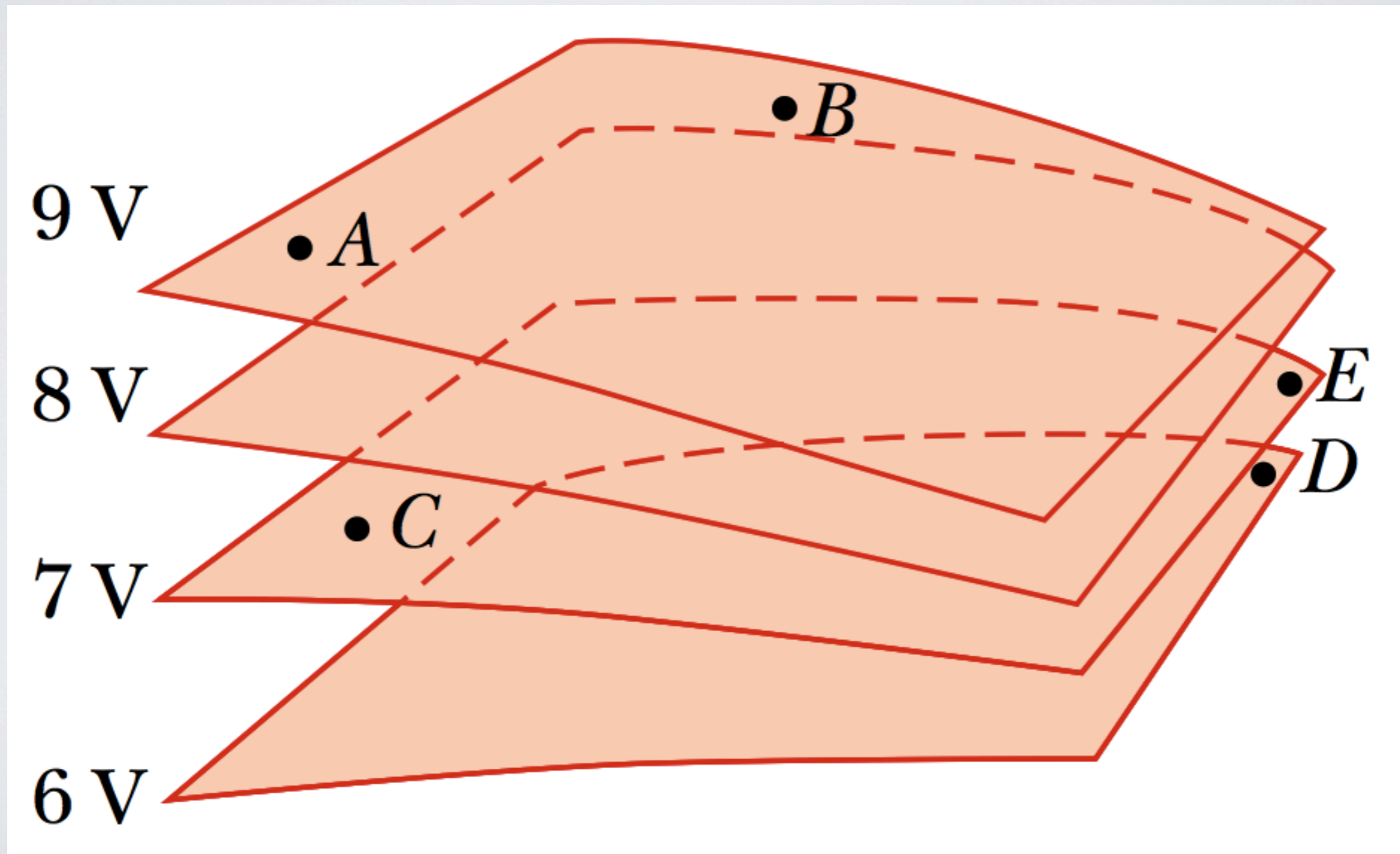


Exercise

A glass rod is positively charged. The figure shows an end view of the rod. A negatively charged particle moves in a circular arc around the glass rod. Is the work done on the charged particle by the rod's electric field positive, negative, or zero?



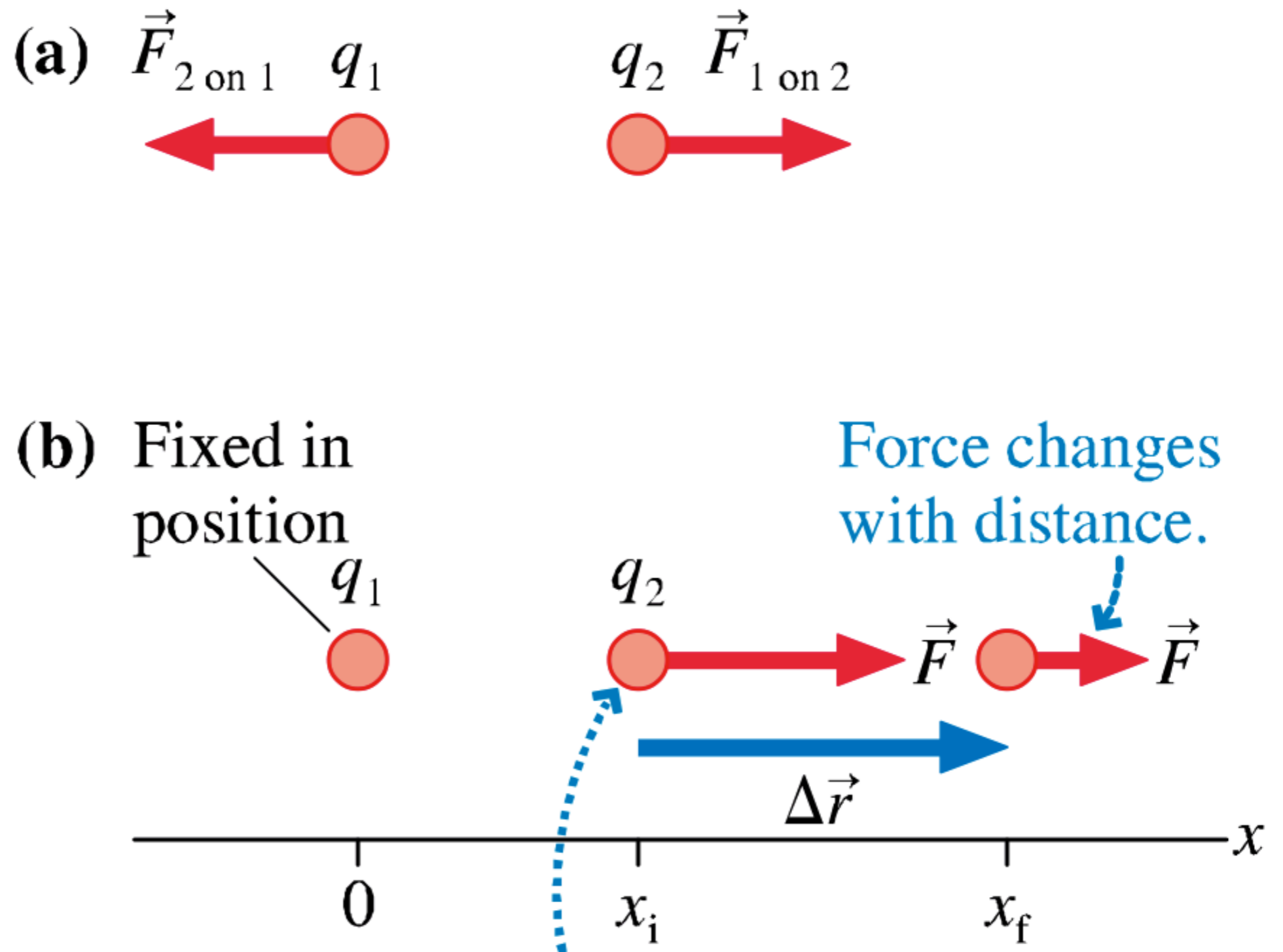
The labeled points in the figure are on a series of equipotential surfaces associated with an electric field. Rank (from greatest to least) the work done by the electric field on a positively charged particle that moves from A to B ; from B to C ; from C to D ; from D to E .



Exercise

|| The electric field strength is $20,000 \text{ N/C}$ inside a parallel-plate capacitor with a 1.0 mm spacing. An electron is released from rest at the negative plate. What is the electron's speed when it reaches the positive plate?

The Potential Energy of Point Charges



The interaction between two point charges.

q_1 does work on q_2 as q_2 moves from x_i to x_f .

The potential energy of the two charges is related to the work done by

$$\Delta U_{\text{elec}} = U_{\text{f}} - U_{\text{i}} = -W_{\text{elec}}(\text{i} \rightarrow \text{f}) = \frac{Kq_1q_2}{x_{\text{f}}} - \frac{Kq_1q_2}{x_{\text{i}}}$$

By comparing the left and right sides of the equation we see that the potential energy of the two-point-charge system is

$$U_{\text{elec}} = \frac{Kq_1q_2}{x}$$

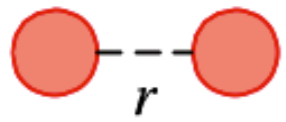
If more than two charges are present, the potential energy is the sum of the potential energies due to all pairs of charges:

$$U_{\text{elec}} = \sum_{i < j} \frac{Kq_iq_j}{r_{ij}}$$

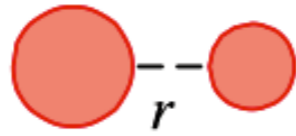
where r_{ij} is the distance between q_i and q_j . The summation contains the $i < j$ restriction to ensure that each pair of charges is counted only once.

Exercise

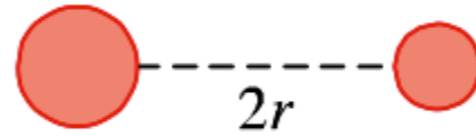
Rank in order, from largest to smallest, the potential energies U_a to U_d of these four pairs of charges. Each $+$ symbol represents the same amount of charge.



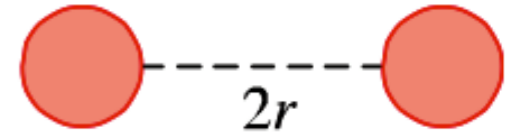
(a)



(b)



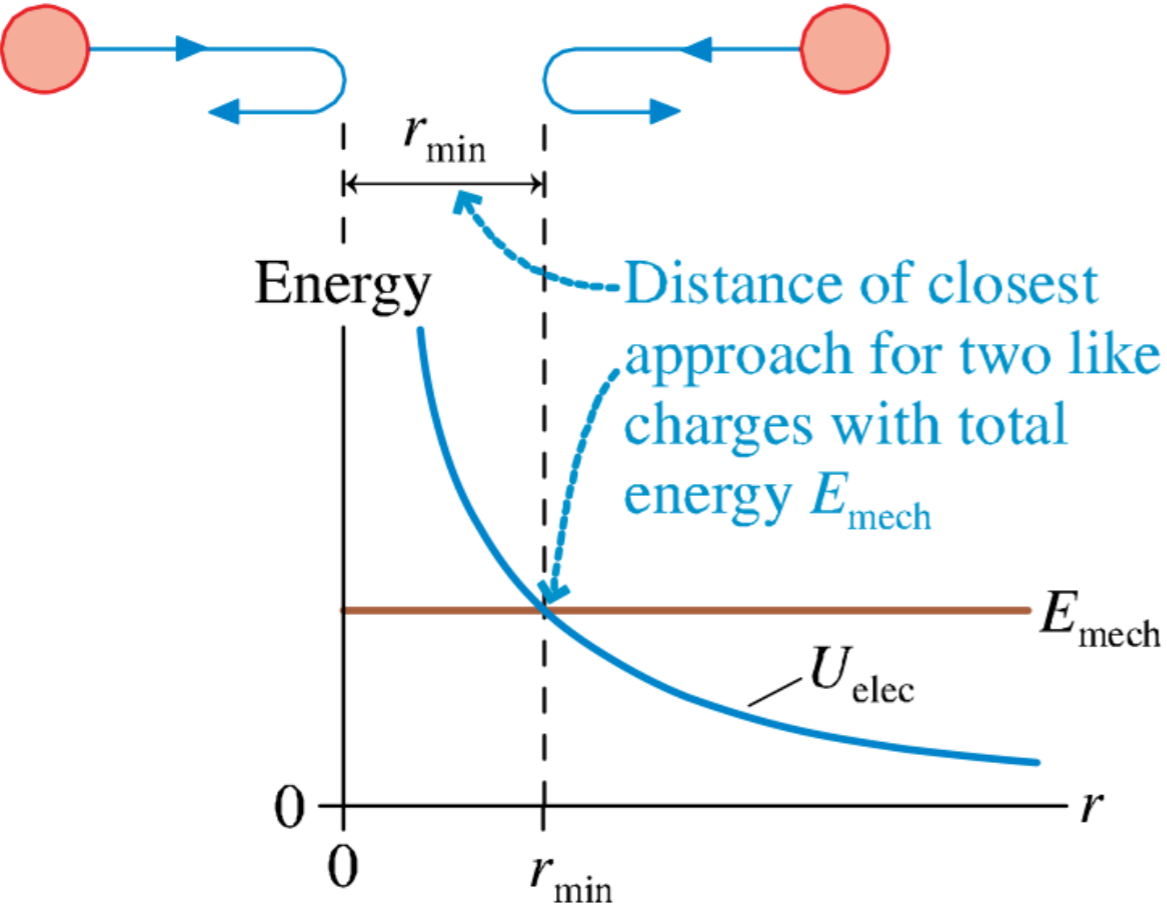
(c)



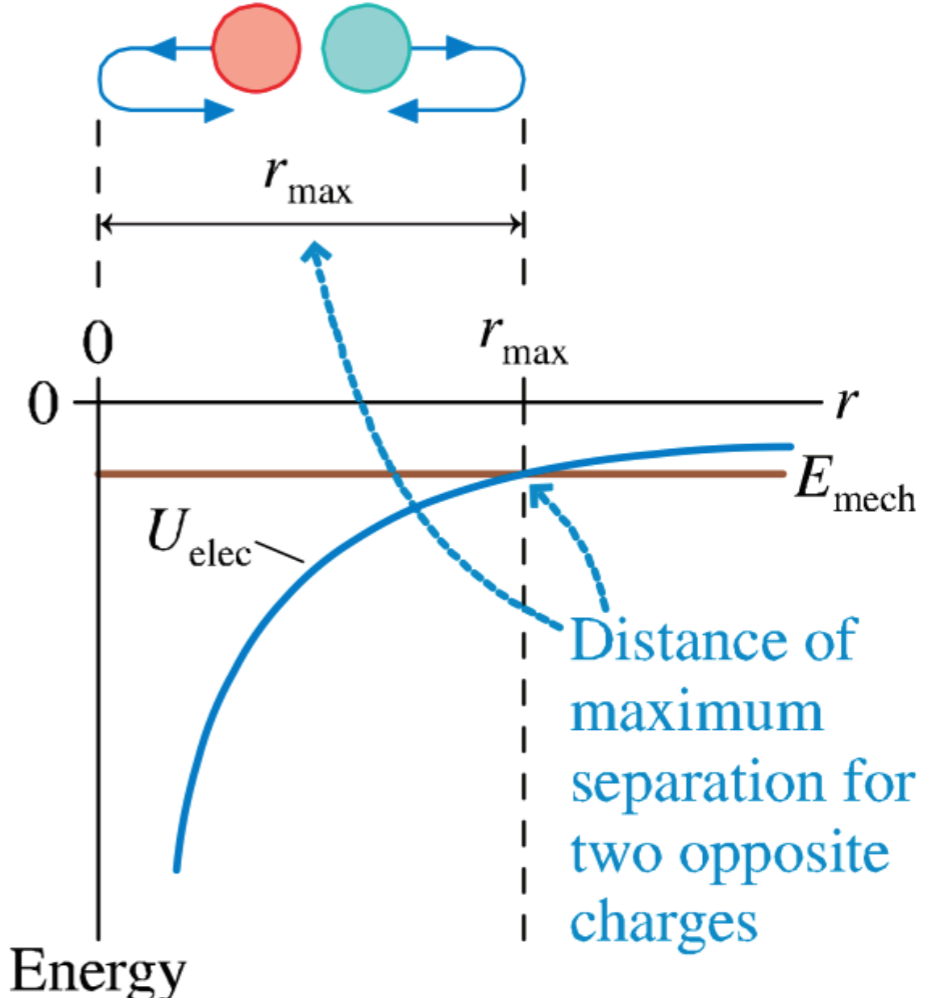
(d)

The potential-energy diagrams for two like charges and two opposite charges.

(a) Like charges



(b) Opposite charges

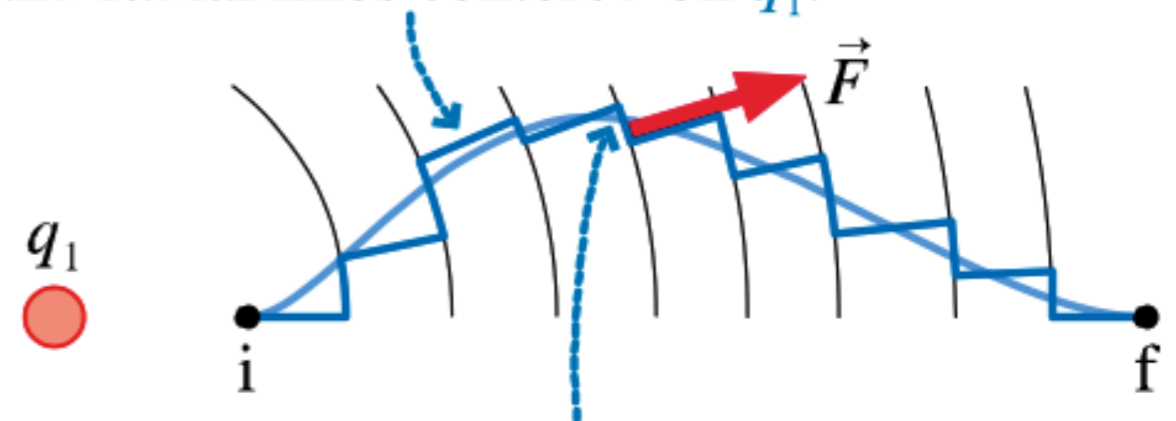


Calculating the work done
as q_2 moves along a
curved path from i to f .

An alternative path for q_2 to move from i to f



Approximate the path using circular arcs
and radial lines centered on q_1 .



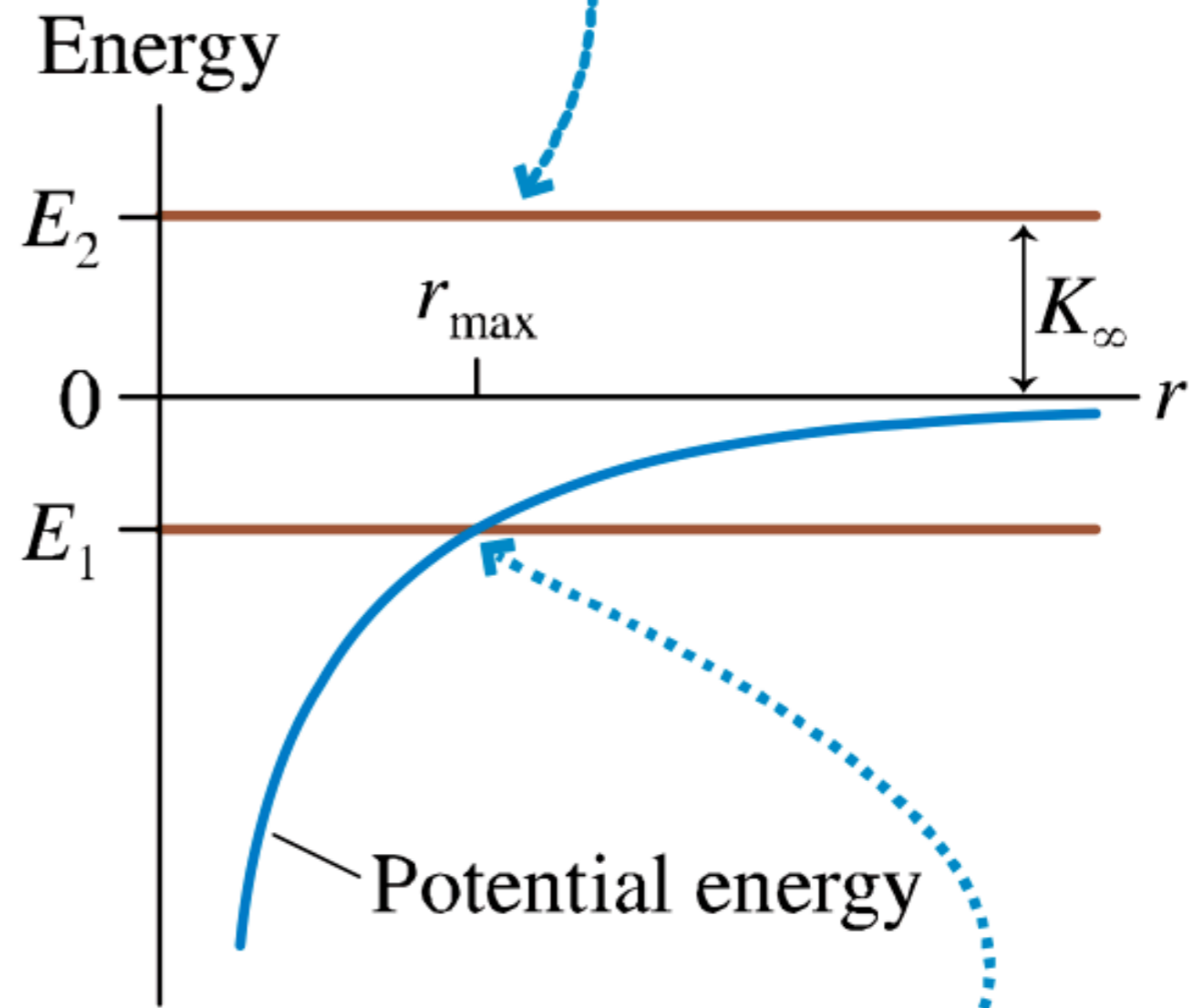
The electric force does zero work as q_2
moves along a circular arc because the force
is perpendicular to the displacement.



All the work is done along the radial
line segments, which are equivalent
to a straight line from i to f .

A system with $E_{\text{mech}} < 0$
is a *bound system*.

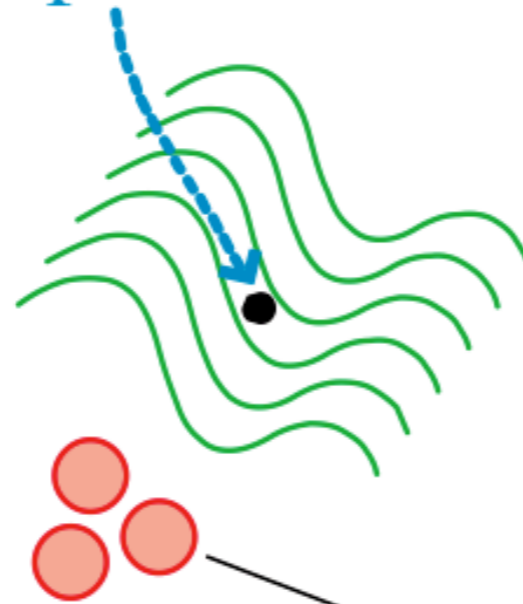
Two particles with total energy $E_2 > 0$
can move apart forever. Their kinetic
energy is K_∞ as $r \rightarrow \infty$.



Two particles with total energy $E_1 < 0$
are a bound system. They can't get
farther apart than r_{max} .

The Electric Potential

The potential at this point is V .



The source charges alter the space around them by creating an electric potential.

Source charges



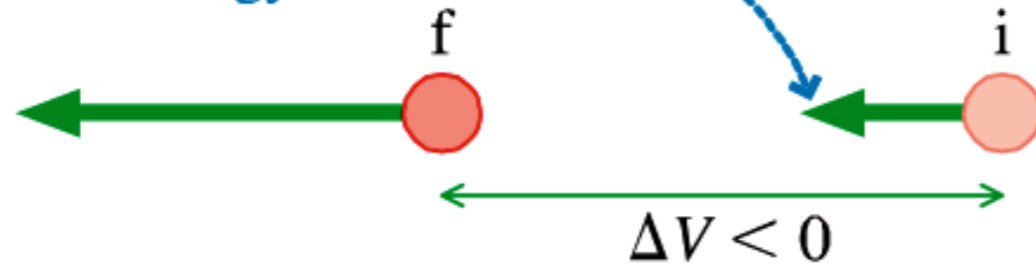
If charge q is in the potential, the electric potential energy is

$$U_{q+\text{sources}} = qV.$$

Source charges alter the space around them by creating an electric potential.

A charged particle speeds up or slows down as it moves through a potential difference.

A positive charge speeds up as it moves through a negative potential difference. Potential energy is transformed into kinetic energy.



A positive charge slows down as it moves through a positive potential difference. Kinetic energy is transformed into potential energy.

Direction of increasing V

Distinguishing electric potential and potential energy.

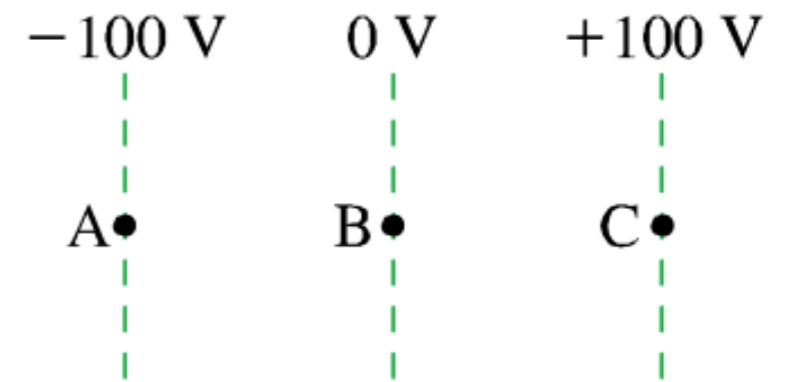
The *electric potential* is a property of the source charges and, as you'll soon see, is related to the electric field. The electric potential is present whether or not a charged particle is there to experience it. Potential is measured in J/C, or V.

The *electric potential energy* is the interaction energy of a charged particle with the source charges. Potential energy is measured in J.

Exercise

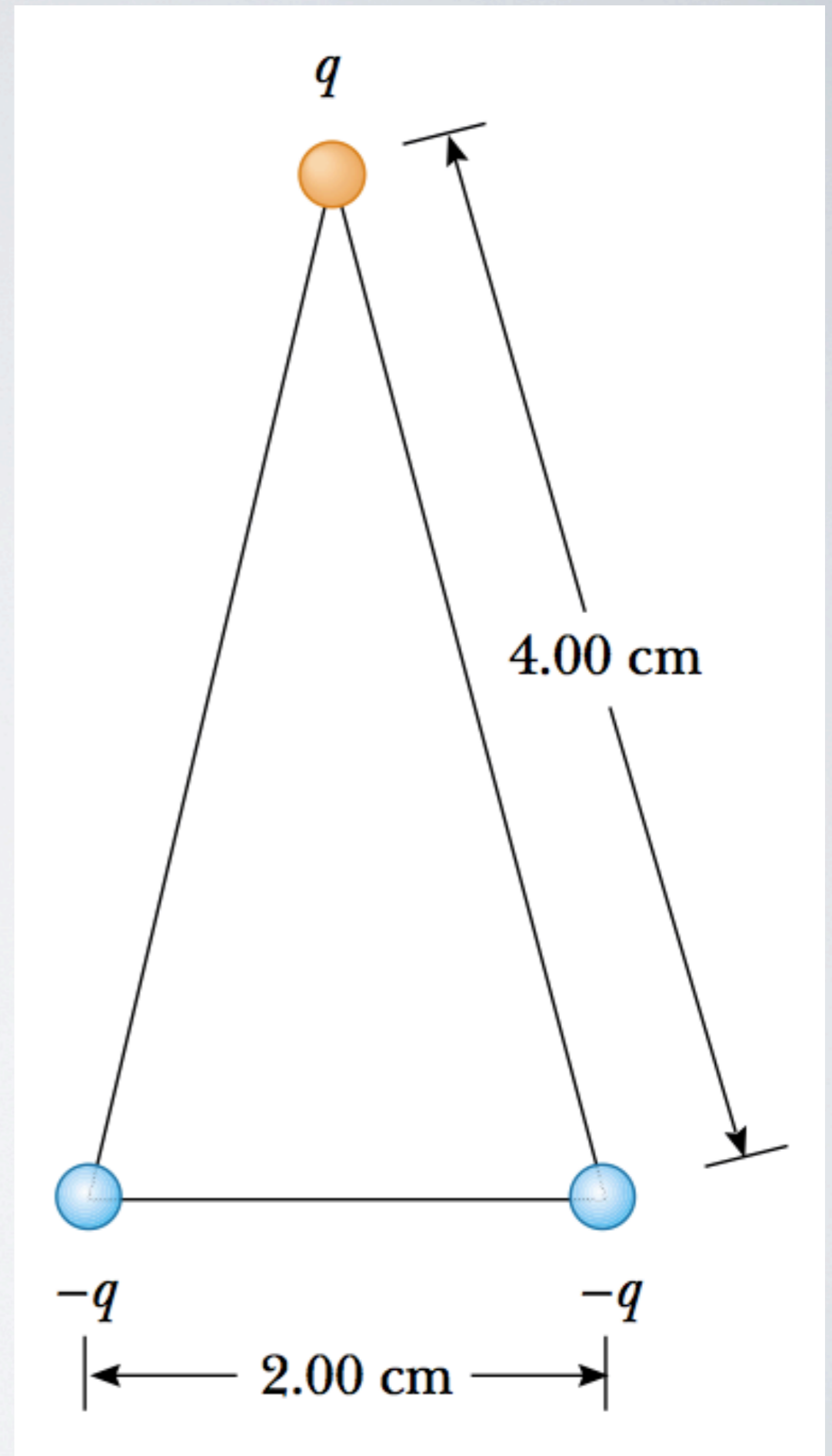
A proton is released from rest at point B, where the potential is 0 V. Afterward, the proton

- Remains at rest at B.
- Moves toward A with a steady speed.
- Moves toward A with an increasing speed.
- Moves toward C with a steady speed.
- Moves toward C with an increasing speed.

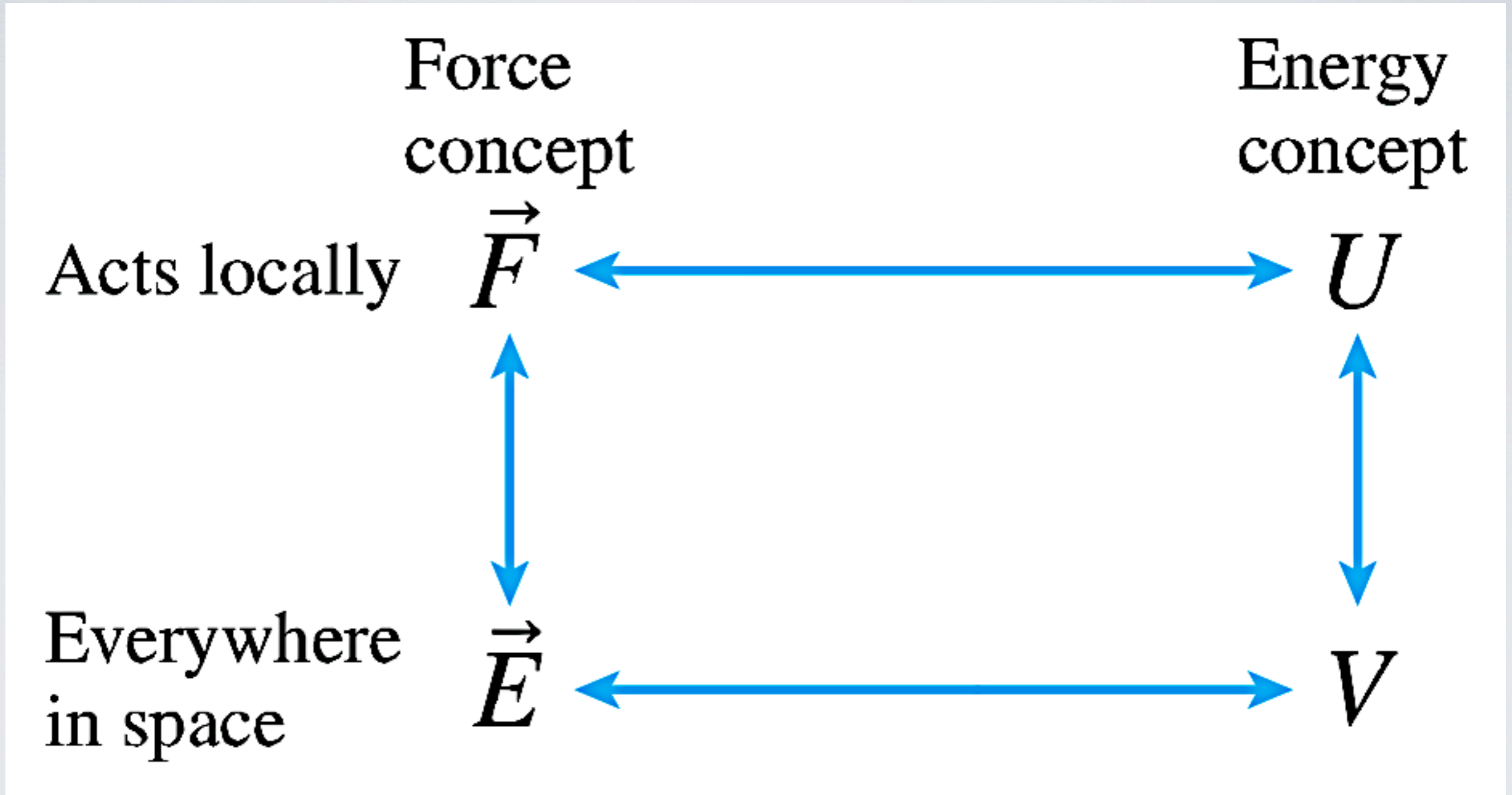


Serway P 25.21, p. 796

The three charges in the figure are at the vertices of an isosceles triangle. Calculate the electric potential at the midpoint of the base, taking $q = 7.00 \mu\text{C}$.



The four key ideas



Seatwork

Serway **25.5**, p. 795

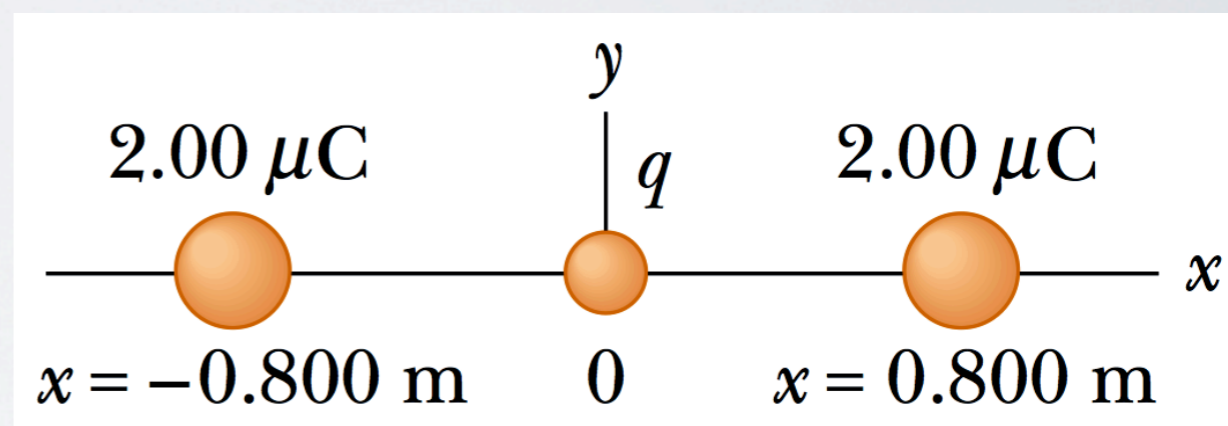
What potential difference is needed to stop an electron having an initial speed of 4.20×10^5 m/s?

Serway **25.9**, p. 795

An electron moving parallel to the x axis has an initial speed of 3.70×10^6 m/s at the origin. Its speed is reduced to 1.40×10^5 m/s at the point $x = 2.00$ cm. Calculate the potential difference between the origin and that point. Which point is at the higher potential?

Serway **25.17**, p. 796

Given two $2.00\text{-}\mu\text{C}$ charges, as shown in the figure, and a positive test charge $q = 1.28 \times 10^{-18}$ C at the origin, (a) what is the net force exerted on q by the two $2.00\text{-}\mu\text{C}$ charges? (b) What is the electric field at the origin due to the two $2.00\text{-}\mu\text{C}$ charges? (c) What is the electric potential at the origin due to the two $2.00\text{-}\mu\text{C}$ charges?



Serway **25.29**, p. 797

A small spherical object carries a charge of 8.00 nC. At what distance from the center of the object is the potential equal to 100 V? 50.0 V? 25.0 V? Is the spacing of the equipotentials proportional to the change in potential?