Electric Potential

electric potential energy U

$$\Delta U = U_f - U_i = -W.$$

$$U = -W_{\infty}.$$

$$W = \vec{F} \cdot \vec{d}.$$

Reminder: 1 Joule = 1 Newton * 1 meter

Electric Potential

Energy/unit charge: U/Q = J/C

1 Volt = 1 Joule / 1 Coulomb

1 V = 1 kg times m^2 times s^{-3} times A^{-1} (kilogram meter squared per second cubed per ampere)

$$1\ \mathrm{N/C} = \left(1\frac{\mathrm{N}}{\mathrm{C}}\right)\left(\frac{1\ \mathrm{V}\cdot\mathrm{C}}{1\ \mathrm{J}}\right)\left(\frac{1\ \mathrm{J}}{1\ \mathrm{N}\cdot\mathrm{m}}\right)$$

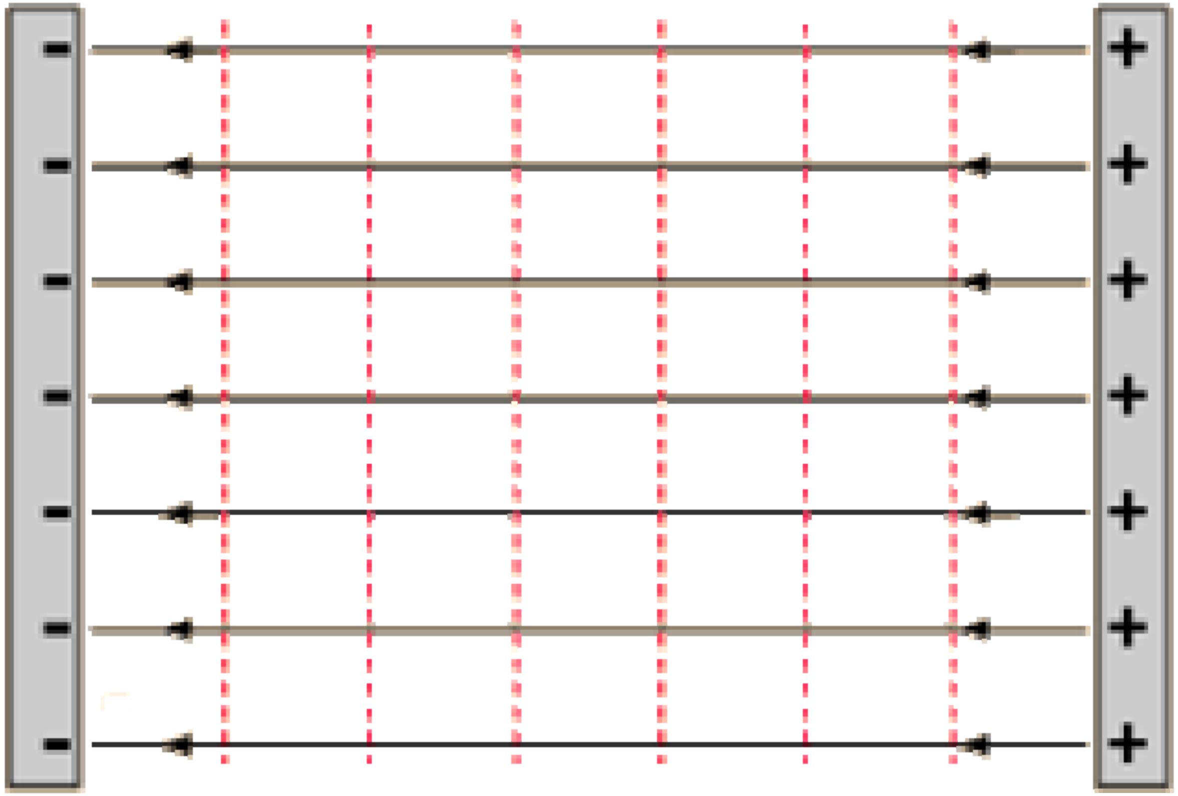
$$= 1\ \mathrm{V/m}.$$

Equipotential Surfaces

Equipotential lines are always perpendicular to the electric field .In three dimensions, the lines form equipotential surfaces. Movement along an equipotential surface requires no work because such movement is always perpendicular to the electric field .

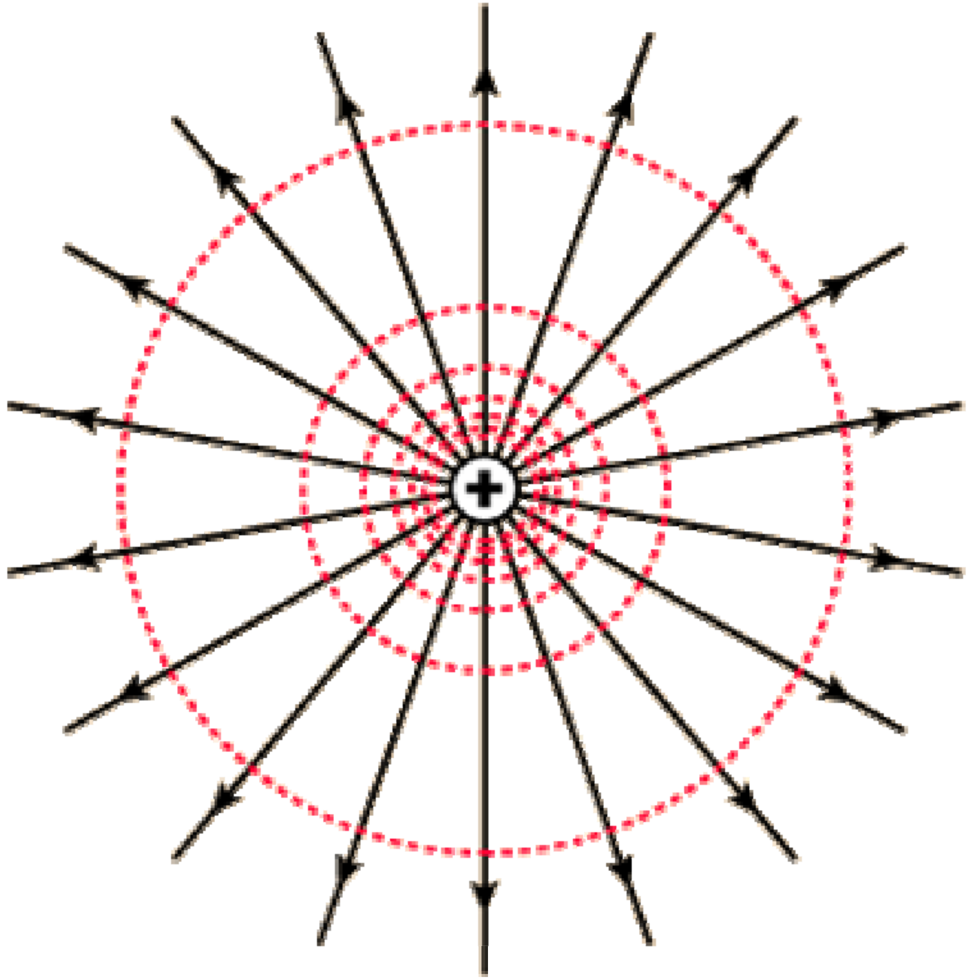
Equipotential Surfaces

For parallel conducting plates the electric field lines are perpendicular to the plates and the equipotential lines are parallel to the plates .



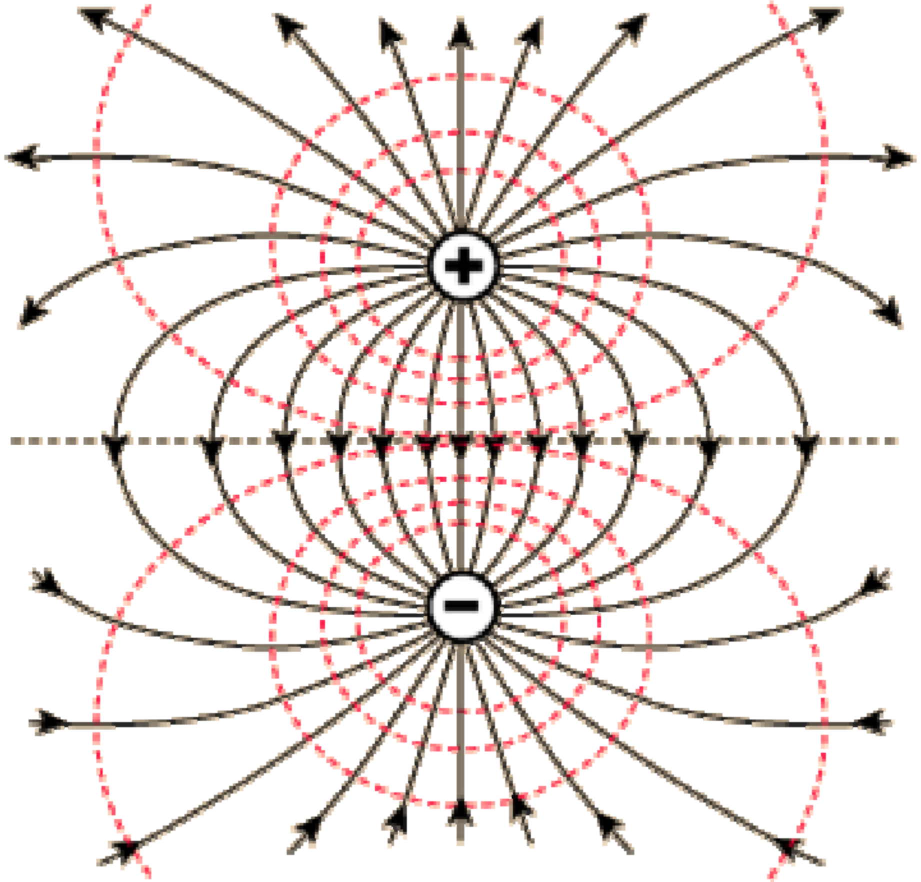
Equipotential Surfaces

the radius r determines the potential. The equipotential lines are therefore circles and a sphere centered on the charge is an equipotential surface. The dashed lines illustrate the scaling of voltage at equal increments - the equipotential lines get further apart with increasing r.

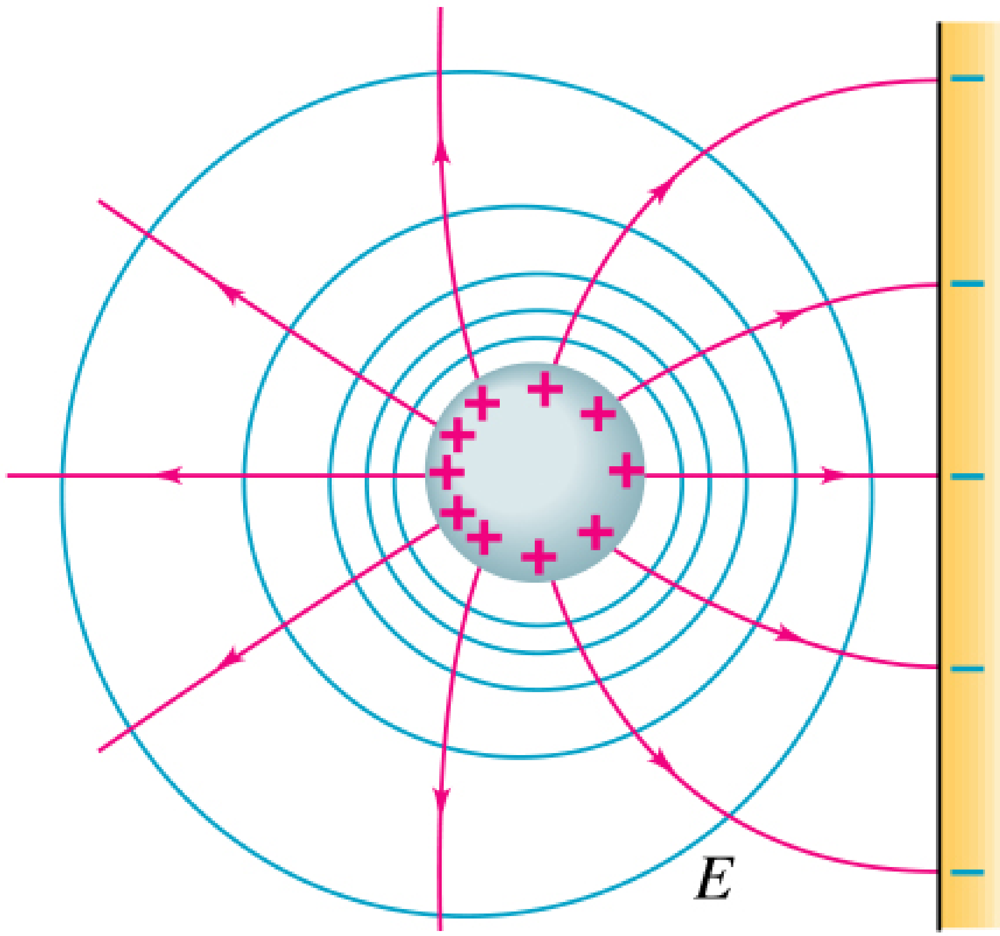


Equipotential Surfaces

The electric potential of a dipole show mirror symmetry about the center point of the dipole. They are everywhere perpendicular to the electric field lines.



Equipotential lines and electric field lines for a charge near a conductor.



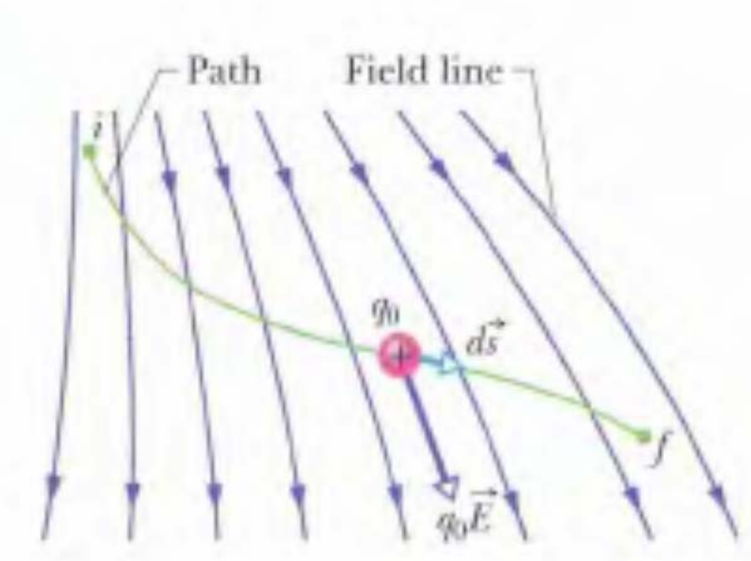
Calculating the Potential from the Field

$$dW = \vec{F}\cdot d\vec{s}.$$

$$\vec{F} = q_0\vec{E}$$

$$dW = q_0\vec{E}\cdot d\vec{s}.$$

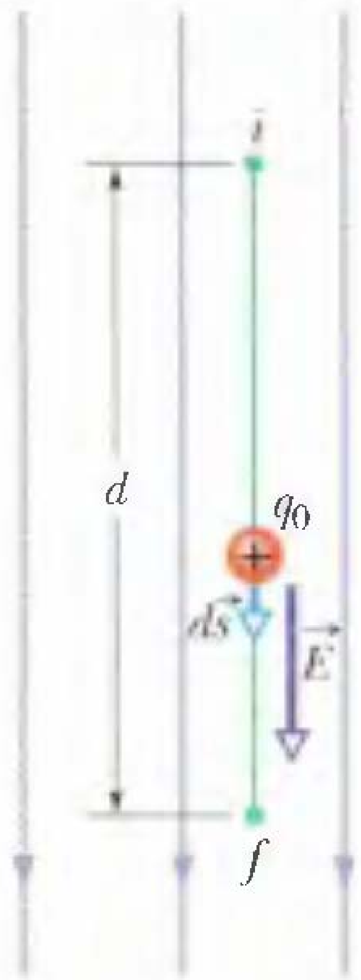
$$W = q_0\int_i^f \vec{E}\cdot d\vec{s}.$$



$$V_f - V_i = -\int_i^f \vec{E}\cdot d\vec{s}.$$

$$V_i = 0,\quad V = -\int_i^f \vec{E}\cdot d\vec{s},$$

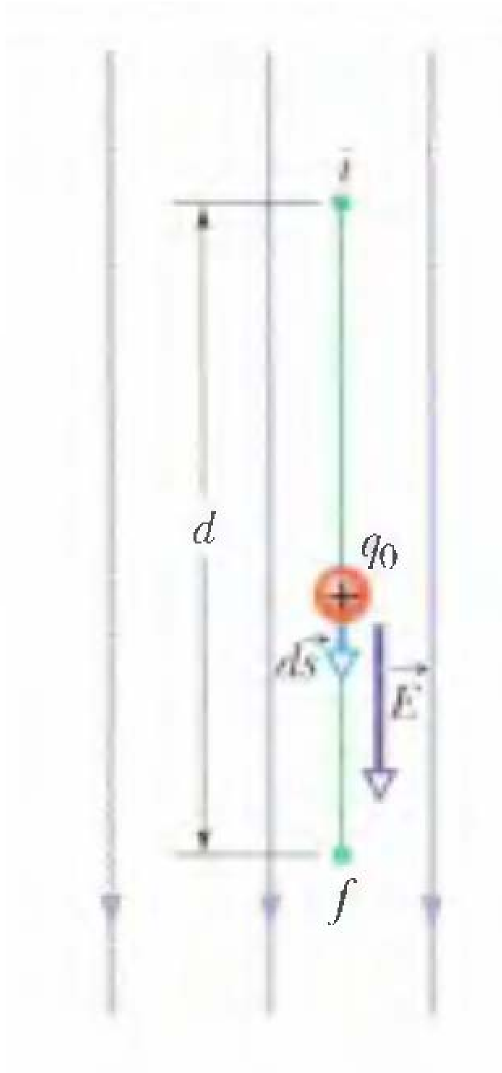
(a) Figure 24-5*a* shows two points *i* and *f* in a uniform electric field $\vec{E}$. The points lie on the same electric field line (not shown) and are separated by a distance *d*. Find the potential difference $V_f - V_i$ by moving a positive test charge q_0 from *i* to *f* along the path shown, which is parallel to the field direction.



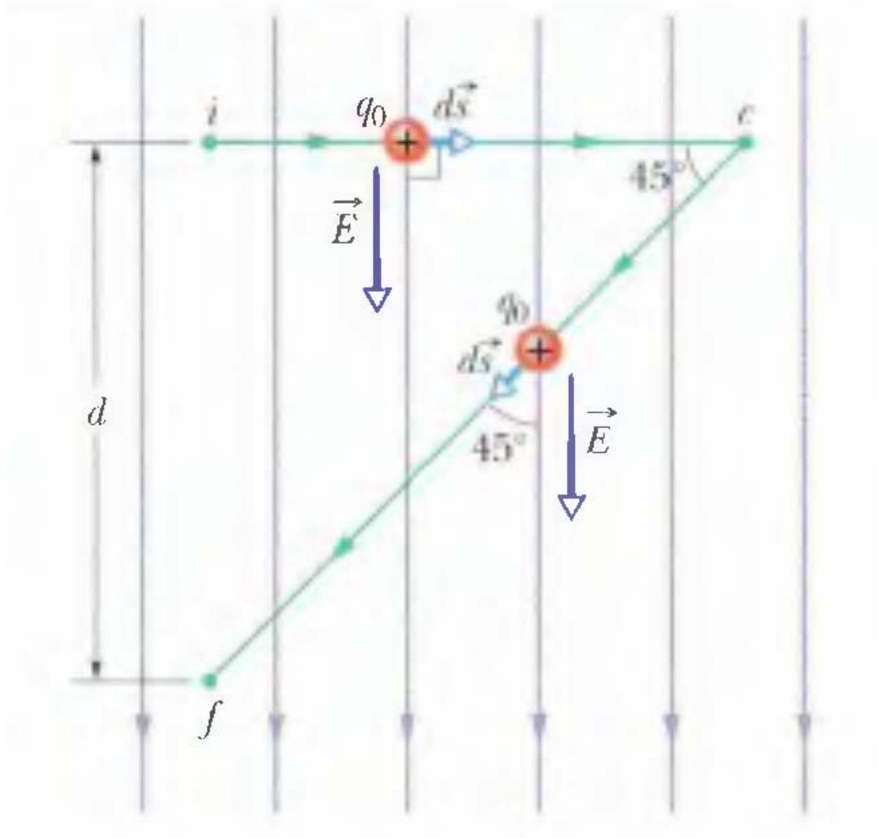
$$\vec{E} \cdot d\vec{s} = E\,ds\cos\theta = E\,ds.$$

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s} = -\int_i^f E\,ds.$$

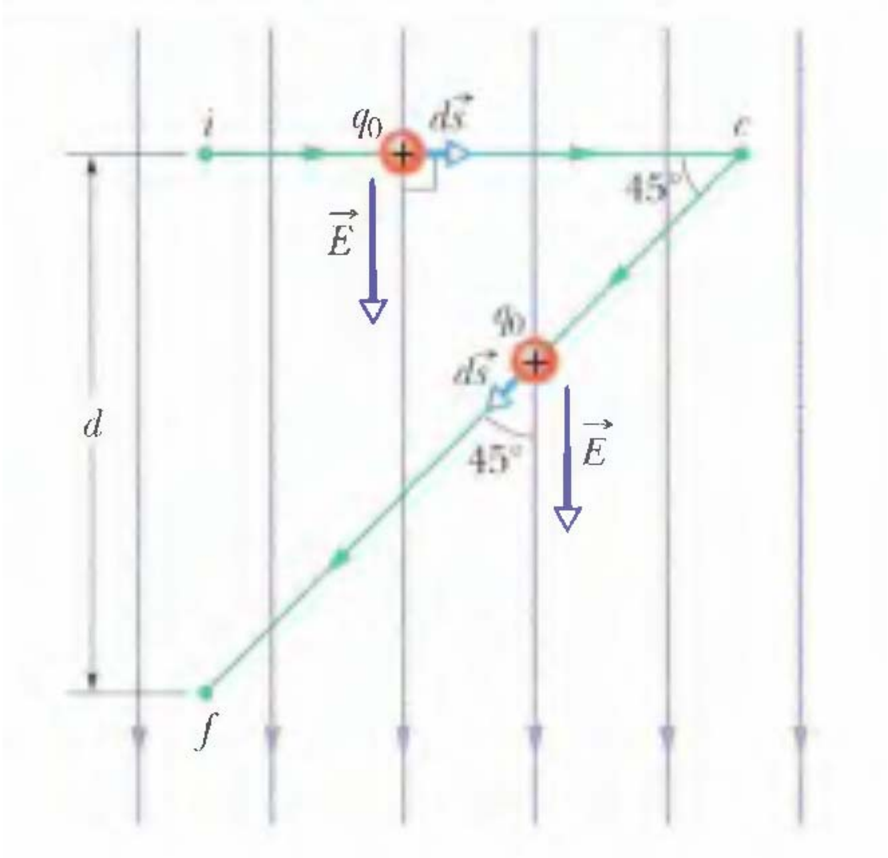
$$V_f - V_i = -E\int_i^f ds = -Ed,$$



(b) Now find the potential difference $V_f - V_i$ by moving the positive test charge q_0 from i to f along the path icf shown in Fig. 24-5b.

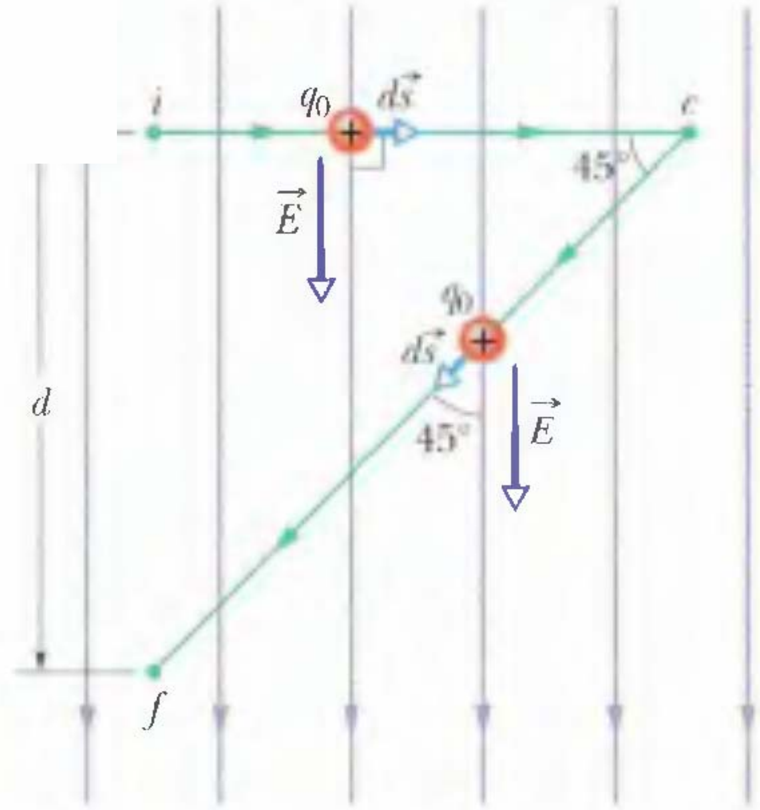


At all the points along ic, the displacement is perpendicular to the Electric field and hence the dot product is 0. thus the change in V is 0.



$$V_f - V_i = -\int_c^f \vec{E} \cdot d\vec{s} = -\int_c^f E(\cos 45^\circ)\, ds$$

$$= -E(\cos 45^\circ) \int_c^f ds.$$



$$V_f - V_i = -E(\cos 45^\circ) \frac{d}{\sin 45^\circ} = -Ed.$$

Potential Due to a Point Charge

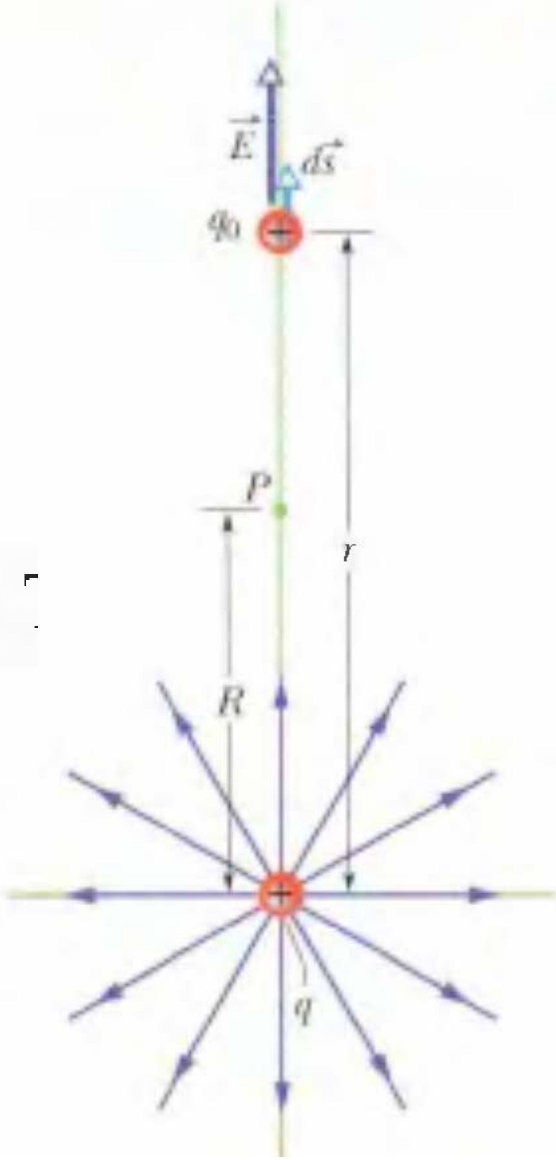
$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}.$$

$$\vec{E} \cdot d\vec{s} = E \cos \theta \, ds.$$

$$V_f - V_i = -\int_R^{\infty} E \, dr.$$

set $V_f = 0$ (at ∞) and $V_i = V$ (at R).

$$E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2}.$$

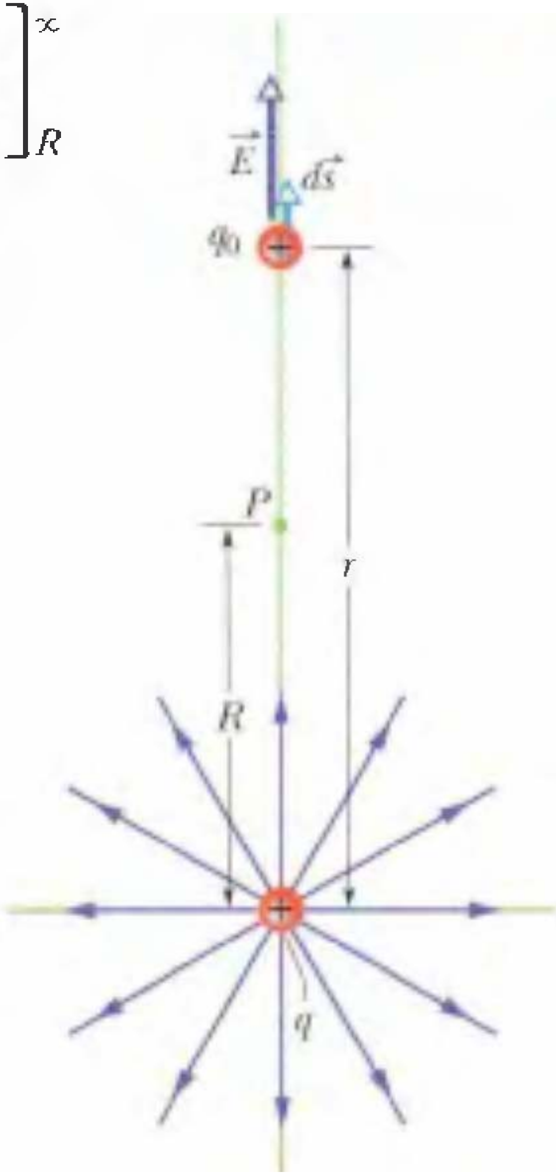


Potential Due to a Point Charge

$$0 - V = -\frac{q}{4\pi\varepsilon_0}\int_R^\infty \frac{1}{r^2}\,dr = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\right]_R^\infty$$

$$= -\frac{1}{4\pi\varepsilon_0}\frac{q}{R}.$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$



The field strength between two equal but oppositely charged parallel plates

$$E = \frac{V}{d}$$

A potential difference of 150 V is applied to two parallel metal plates. If an electric field of 5000 V/m is produced between the plates, how far apart are the plates?

0.018 (1.8 × 10)(9.8) and $V = \underline{496\ \text{V}}$

Two large parallel metal plates (3.00 mm apart) are charged to a potential difference of 12 V. (*a*) What is the field between them? (*b*) They are now disconnected from the battery and pulled apart to 5.00 mm. What is the new electric field between them and what is now the potential difference?

The potential difference between the two plates in Fig. 26-19 is 100 V. If the system is in vacuum, what will be the speed of a proton released from plate B just before it hits plate A?

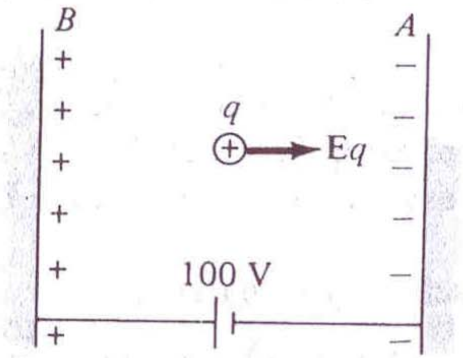


Fig. 26-19

The difference in potential, $V_{AB} \equiv V_A - V_B$, between wires A and B, Fig. 26-18, as measured by a voltmeter is 6000 V. A small sphere having mass 0.150 kg and carrying a charge $q = +500\ \mu C$ is released from rest at a point very near wire A and allowed to move to wire B. **(a)** Does V_{AB} depend on s, the distance between the wires? **(b)** What work W_E is done by electric forces on the sphere? **(c)** With what speed u will the sphere arrive at B? **(d)** What is the average field E_{avg} between A and B?

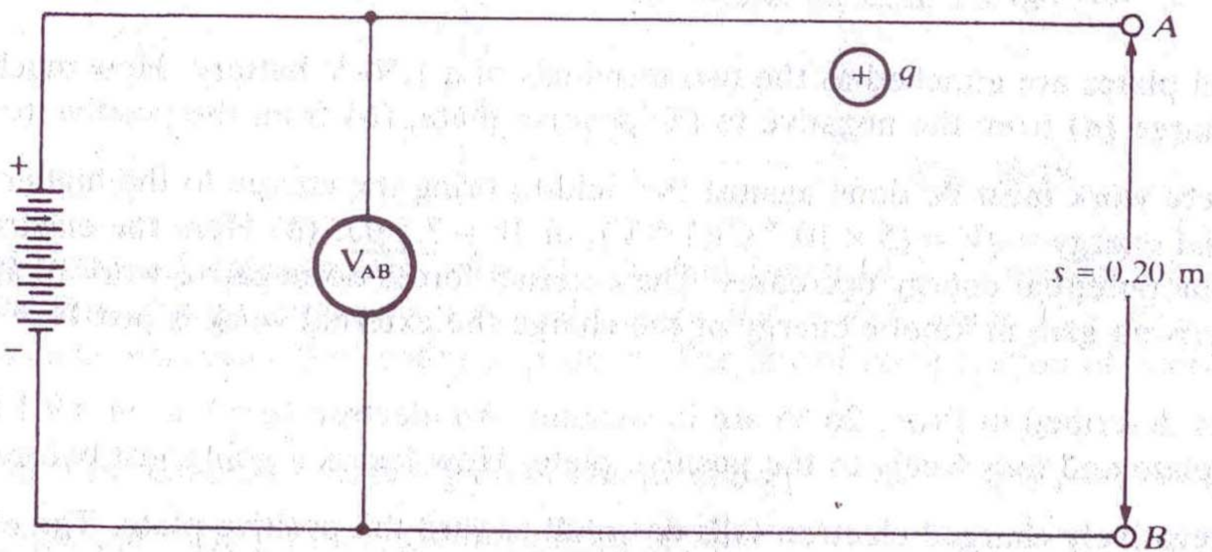


Fig. 26-18