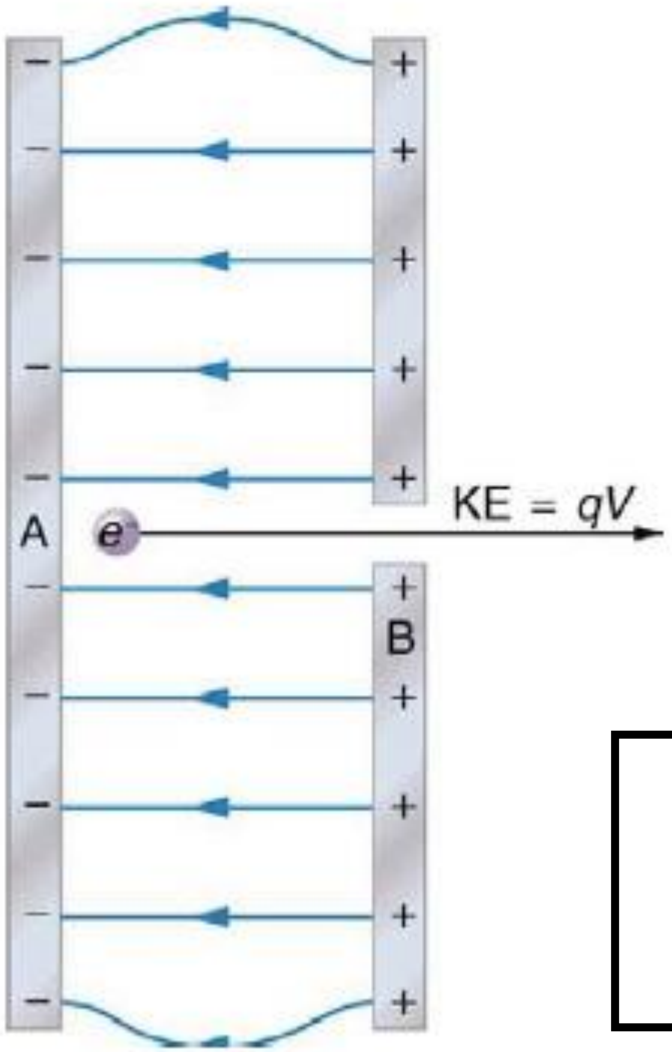
Exercise 1

1. Find the ratio of speeds of an electron and a negative hydrogen ion (one having an extra electron) accelerated through the same voltage, assuming non-relativistic final speeds. Take the mass of the hydrogen ion to be

1.67×10^{-27} kg.

$$\Delta U = q\,\Delta V = -\Delta K$$



potential energy lost is gained as kinetic energy

The kinetic energy only depends on the voltage difference, not on the distance between the plates

$$\frac{mv^2}{2} = qV$$

eV = electron-volt = energy of electron accelerated in 1V

$$1\text{eV} = 1.6\ \ 10^{-19}\ \text{J}$$

$$v = \sqrt{\frac{2qV}{m}}$$

$$\frac{v_{el}}{v_{ion}} = \sqrt{\frac{m_{ion}}{m_{el}}} = \sqrt{\frac{1.67\times10^{-27}}{9.11\times10^{-31}}} = 42$$

2. An evacuated tube uses an accelerating voltage of 40 kV to accelerate electrons to hit a copper plate and produce x rays. Non-relativistically, what would be the maximum speed of these electrons?

Non-relativistically : does not take into account "special relativity"

$$v \ll c$$

speed of light

c = 3 x 10^8 m/s

$$\frac{mv^2}{2} = qV$$

q = 1.6 x 10^{-19} C

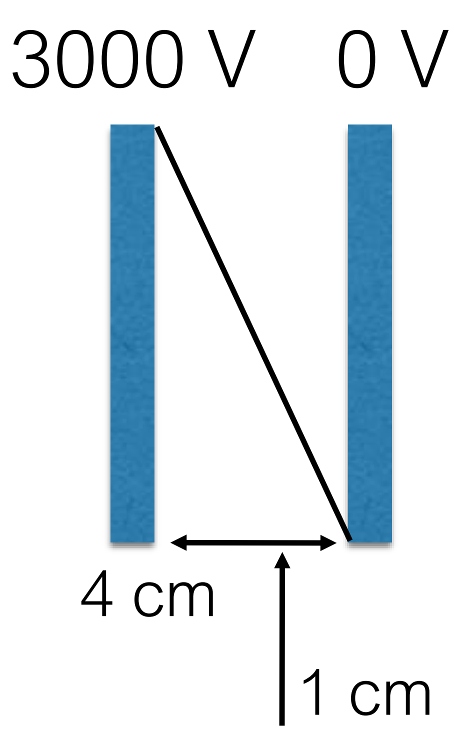
m_e = 9.11 x 10^{-31} C

$$v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 4 \times 10^{4}}{9,11 \times 10^{-31}}} = 1.19 \times 10^{8} \text{ m/s}$$

not really "non-relativistic" !!!

15. The electric field strength between two parallel conducting plates separated by 4.00 cm is 7.50×10^4 V/m . (a) What is the potential difference between the plates? (b) The plate with the lowest potential is taken to be at zero volts. What is the potential 1.00 cm from that plate (and 3.00 cm from the other)?

$$V = E\,D = 7.5 \text{ x } 10^4\,\mathrm{V/m} \text{ x } .04\,\mathrm{m} = 3000\,\mathrm{V}$$



$$\frac{1}{4} \text{ x } 3000\,\mathrm{V} = 750\,\mathrm{V}$$

17. (a) Will the electric field strength between two parallel conducting plates exceed the breakdown strength for air (3.0×10^6 V/m) if the plates are separated by 2.00 mm and a potential difference of 5.0×10^3 V is applied? (b) How close together can the plates be with this applied voltage?

$$\frac{5 \times 10^3\,\mathrm{V}}{0.002\,\mathrm{m}} = 2.5 \times 10^6\,\mathrm{V/m}$$

OK

$$\frac{5 \times 10^3\,\mathrm{V}}{3 \times 10^6\,\mathrm{V/m}} = 1.67\,\mathrm{mm}$$

24. A 0.500 cm diameter plastic sphere, used in a static electricity demonstration, has a uniformly distributed 40.0 pC charge on its surface. What is the potential near its surface?

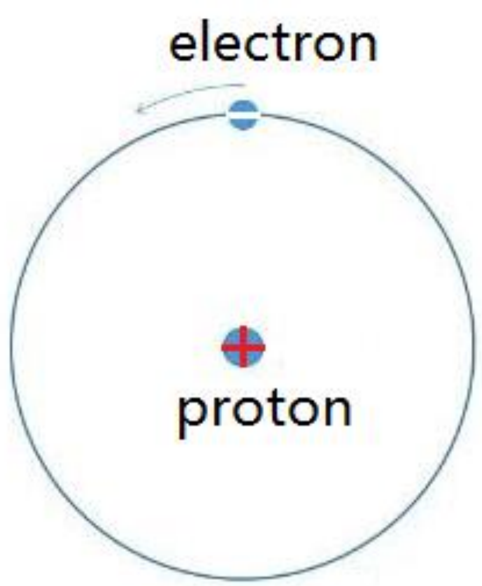
It might be beyond your knowledge

=

sphere with uniform charge = **point charge**

$$V = \frac{Q}{4\pi\varepsilon_0\, d} = \frac{40\ \mathrm{pC}}{4\pi\varepsilon_0\ 0.0025\ \mathrm{m}}$$ =144 V

25. What is the potential 0.530×10^{-10} m from a proton (the average distance between the proton and electron in a hydrogen atom)?



$$V = \frac{Q}{4\pi\varepsilon_0 d} = \frac{1.6 \times 10^{-19}\,\mathrm{C}}{4\pi\varepsilon_0\, 0.53 \times 10^{-10}\ \mathrm{m}} = 27.1\ V$$

27. How far from a $1.00\ \mu C$ point charge will the potential be 100 V? At what distance will it be 2.00×10^2 V ?

$$V = \frac{Q}{4\pi\varepsilon_0 d}$$

$$d = \frac{Q}{4\pi\varepsilon_0 V} \quad = \frac{10^{-6}\,\mathrm{C}}{4\pi\varepsilon_0 100\,\mathrm{V}} \quad = 90\,\mathrm{m}$$

200 V : $45\,\mathrm{m}$

29. If the potential due to a point charge is 5.00×10^{2} V at a distance of 15.0 m, what are the sign and magnitude of the charge?

$$Q = V\,4\pi\varepsilon_0\,d = 500\ \mathrm{V} \times 111 \times 10^{-12} \times 15\ \mathrm{m}$$

$$= 8.33 \times 10^{-7} C = 0.83\ \mu C$$

If the distance between the two positive point charges is halved, and their charge is doubled, then the force between the charges will be:

A. multiplied by 4

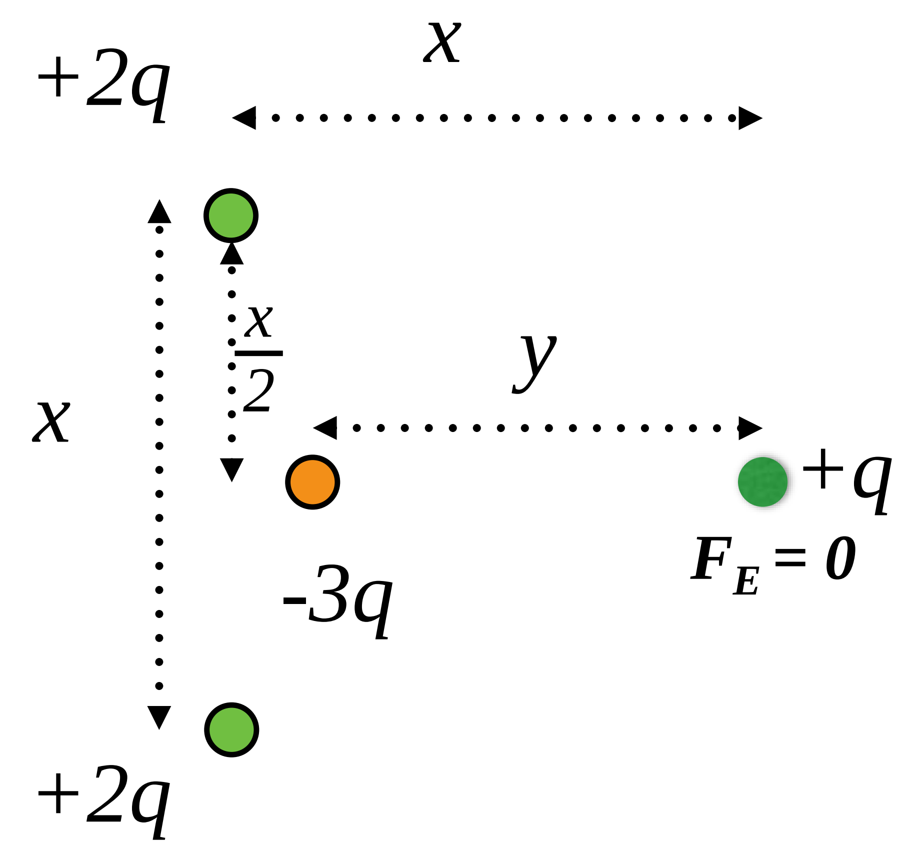
B. the same

C. divided by 2

D. multiplied by 16

$$F_i = \frac{Q_1 Q_2}{4\pi\varepsilon_0 d^2} \qquad F_f = \frac{2Q_1\, 2Q_2}{4\pi\varepsilon_0 \left(\frac{d}{2}\right)^2} = 16\frac{Q_1 Q_2}{4\pi\varepsilon_0 d^2}$$

The figure below shows four point charges. If the net electric force on the $+q$ charge is zero, what is the value of y/x



A. 0.5

B. 0.67

C. 1.05

D. 1.33

$$\frac{2\,q\,2q}{4\pi\varepsilon_0\left(x^2+(x/2)^2\right)}\cos\theta = \frac{3\,q\,q}{4\pi\varepsilon_0\,y^2}$$

$$\cos\theta = \frac{x}{\left(x^2+(x/2)^2\right)^{1/2}} = \frac{1}{\sqrt{1.25}} = 0.89$$

$$\frac{y}{x} = \frac{1.25 \quad 3}{4\cos\theta} = 1.05$$

A metal sphere is placed in a uniform electric field of 100 V/m. What is the electric field inside the sphere?

A. 0 V/m

B. 100 V/m

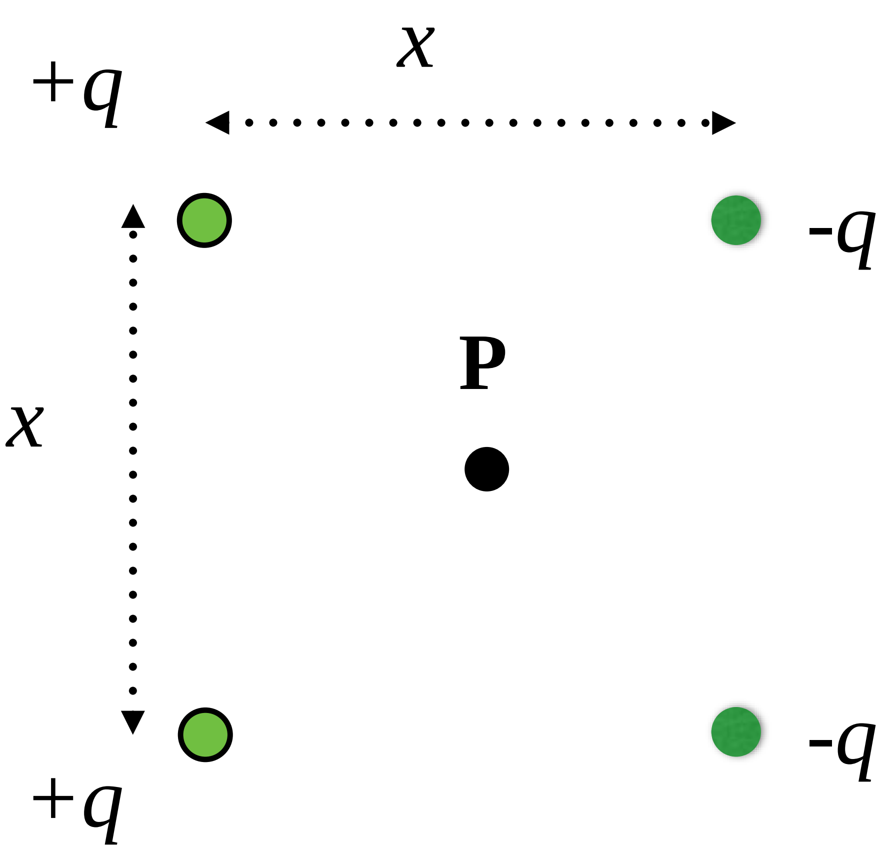
C. 50 V/m

D. 200 V/m

A charge +*Q* is fixed in position. Another small sphere of charge -*q* is placed near the first charge and released from rest. The small sphere will move toward the first charge with

A. decreasing velocity and decreasing acceleration
B. decreasing velocity and increasing acceleration
C. increasing velocity and decreasing acceleration
D. increasing velocity and increasing acceleration

What is the potential at point **P**, if q=1 nC, and x=1 m?



A. 0 V 

B. 12.7 V

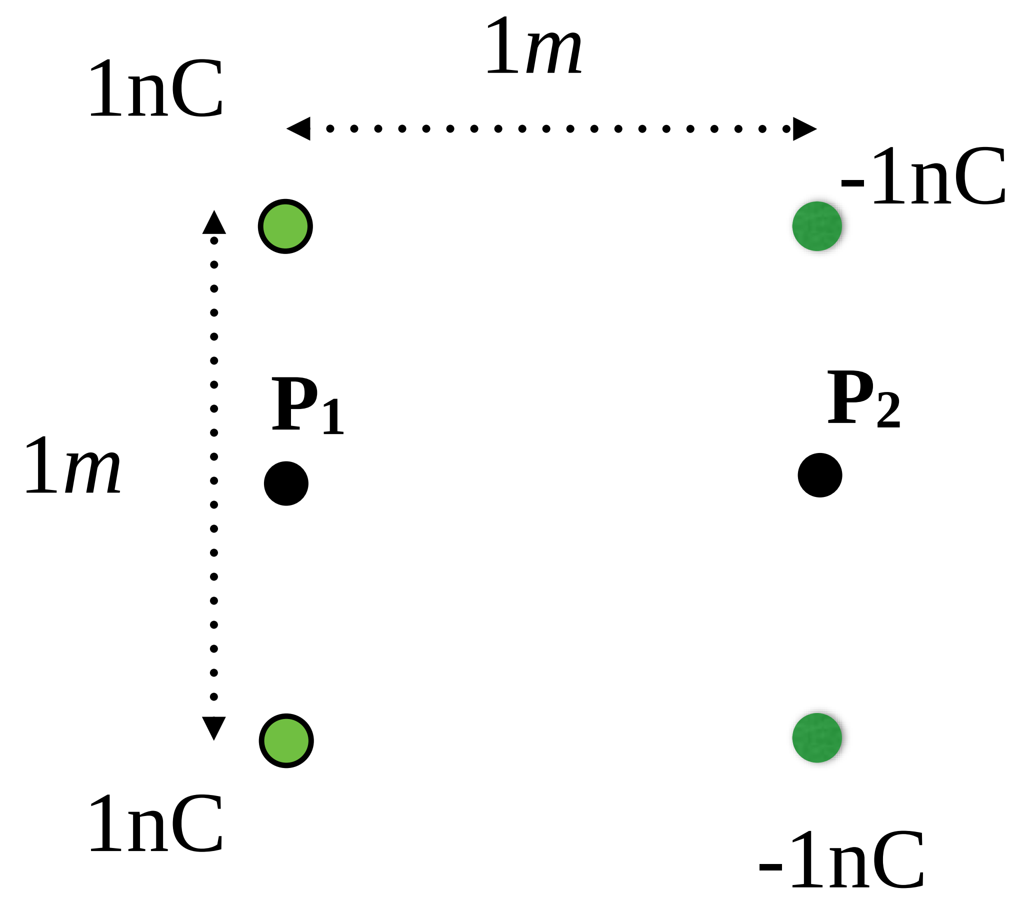
C. 51 V

D. -12.7 V

$$V = \frac{q}{4\pi\varepsilon_0 d}$$

The potential from the positive charges will cancel the potential from the negative charges

A small mass of 1 μg and charge 1 nC is released at point P_1, and is seen to accelerate toward point P_2. What will be its speed at point P_2?



$$V_{P_1} = \sum_{i=1}^{4} \frac{Q_i}{4\pi\varepsilon_0 d_i} = 2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (0.5\text{m})}\right] - 2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (1+0.5^2)^{1/2}}\right]$$

$$V_{P2} = -2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (0.5\text{m})}\right] + 2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (1+0.5^2)^{1/2}}\right]$$

$$V_{P_1} = \sum_{i=1}^{4} \frac{Q_i}{4\pi\varepsilon_0 d_i} = 2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (0.5\text{m})}\right] - 2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (1+0.5^2)^{1/2}}\right]$$

$$V_{P2} = -2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (0.5\text{m})}\right] + 2\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (1+0.5^2)^{1/2}}\right]$$

$$V_{P1} - V_{P2} = 4\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (0.5\text{m})}\right] - 4\left[\frac{1\text{nC}}{4\pi\varepsilon_0 (1+0.5^2)^{1/2}}\right]$$

$$= \frac{4 \times 1\,\text{nC}}{4\pi\varepsilon_0}\left[\frac{1}{.5} - \frac{1}{(1+0.5^2)^{1/2}}\right] = \frac{4 \times 10^{-9} \times 0.88}{111.2 \times 10^{-12}} = 39.8\,V$$

$$q\,\Delta V = \Delta U = -\Delta K = \frac{mv^2}{2}$$

$$v = \sqrt{\frac{2q\Delta V}{m}} = \sqrt{\frac{2 \quad 10^{-9}\text{C} \quad 39.8\text{ V}}{10^{-9}\text{ kg}}} = 8.82\text{ m/s}$$

What is the surface charge density on a 1 m^2 horizontal charged plate, if a small ball of mass 1 g and charge 1 nC released 1 cm above the plate accelerates upward at a rate of 5 m/s^2 ?

$$F = qE - mg = ma$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

$$\sigma = \frac{2\varepsilon_0 m(a+g)}{q} = \frac{2 \times 8.85 \times 10^{-12} \quad 0.001\text{g} \quad (9.8+5)}{10^{-9}\,\text{C}} = 262\,\mu\text{C/m}^2$$

The electric field *E* at 1 m away from a long wire that carrying a linear density of charge λ is measured to be 9 N/m. What will be its value at a distance of 10 m from the wire?

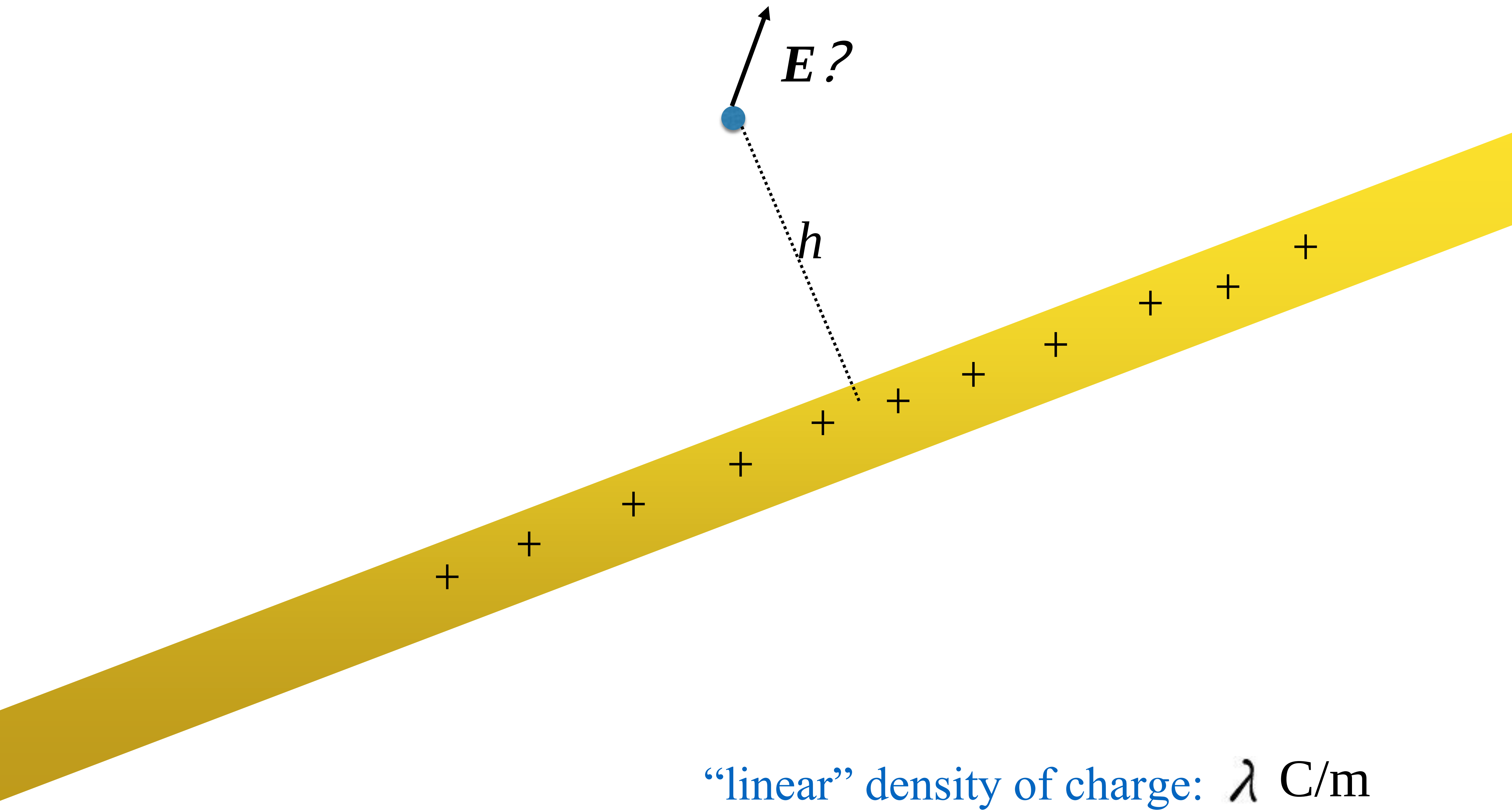
A. 0 V/m

B. 0.9 V/m

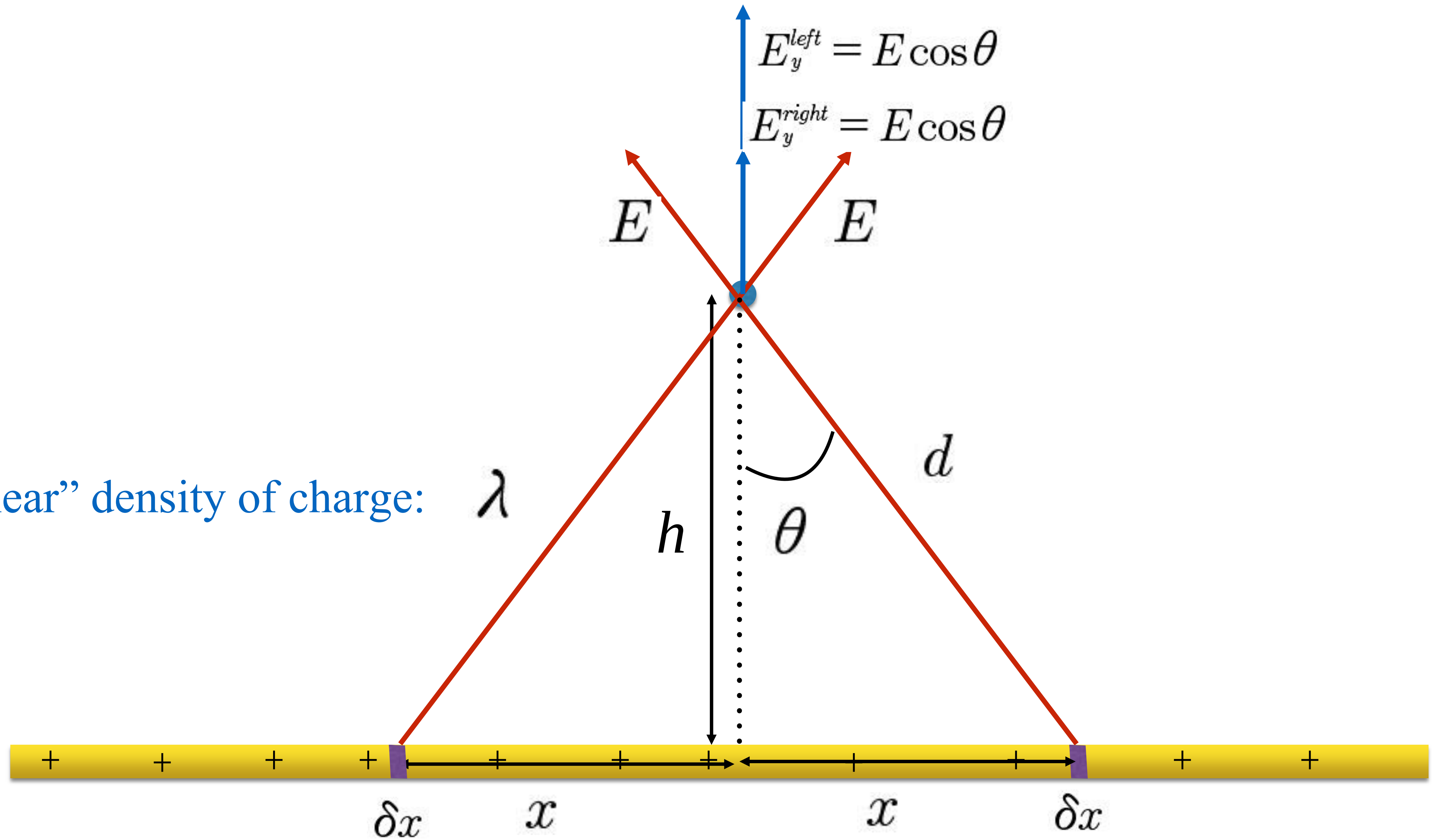
C. 9 V/m

D. 0.09 V/m

What is the electric field from an infinite line of charge ?



"linear" density of charge: λ C/m “linear” density of charge: λ



charge in the small element of wire: $\delta Q = \lambda \delta x$

$$E_y^{left} = E_y^{right} = \frac{\delta Q}{4\pi\varepsilon_0 d^2}\cos\theta = \frac{\lambda \delta x}{4\pi\varepsilon_0 (x^2 + h^2)} \frac{h}{(x^2+h^2)^{1/2}}$$

$$E_y(x) = \frac{2\lambda h\,\delta x}{4\pi\varepsilon_0 (x^2+h^2)^{3/2}} \qquad = \frac{\lambda h^2\,\delta\tilde{x}}{2\pi\varepsilon_0 h^3 (\tilde{x}^2+1)^{3/2}}$$

$$= \frac{\lambda}{2\pi\varepsilon_0 h}\frac{\delta\tilde{x}}{(\tilde{x}^2+1)^{3/2}}$$

$$\boxed{\tilde{x} = \frac{x}{h}} \qquad \delta\tilde{x} = \frac{\delta x}{h}$$

For the total field, we must add all elements from $\tilde{x} = 0$ to $\tilde{x} = \infty$

$$E_y^{total} = \frac{\lambda}{2\pi\varepsilon_0 h}\underbrace{\boxed{\int_0^\infty \frac{d\tilde{x}}{(\tilde{x}^2+1)^{3/2}}}}_{=1} = \frac{\lambda}{2\pi\varepsilon_0 h}$$

depends on *1/h*

The electric field E at 1 m away from a long wire that carrying a linear density of charge λ is measured to be 9 N/m. What will be its value at a distance of 10 m from the wire?

A. 0 V/m

B. 0.9 V/m

C. 9 V/m

D. 0.09 V/m

for a line of charge: $E \propto \frac{1}{d}$

$$\Longrightarrow E(10\text{m}) = \frac{E(1\text{m})}{10} = 0.9 \text{ V/m}$$