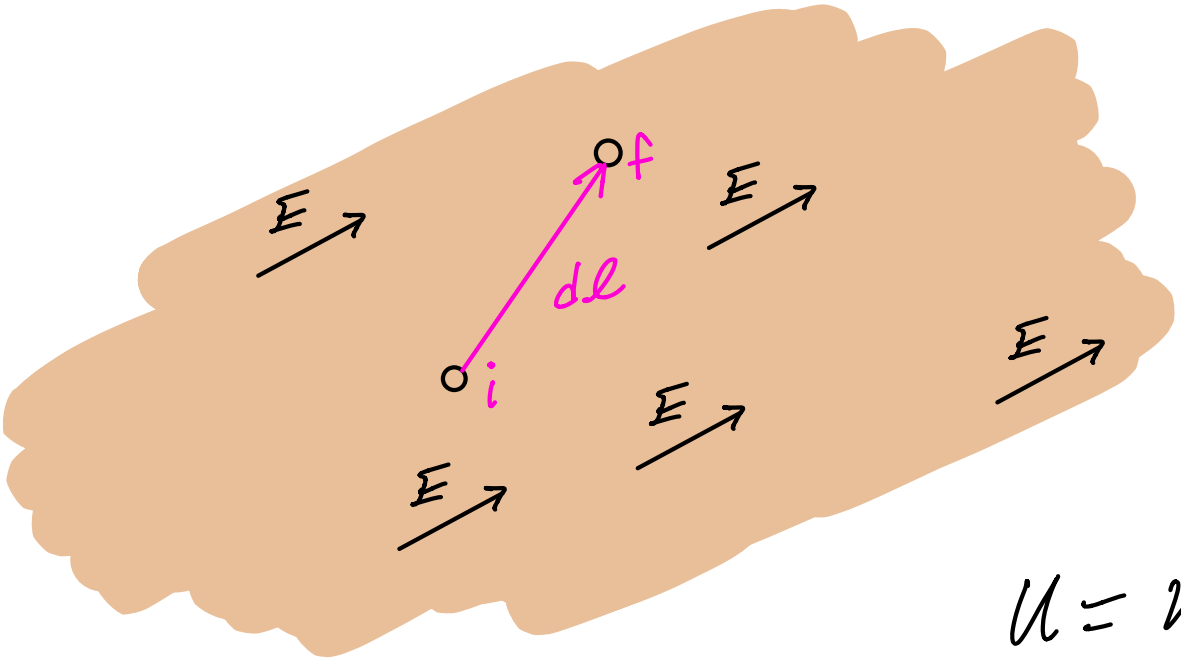


$$U = mgy$$

$$V = \frac{U}{m} = gy$$

$$dW_q = \vec{F} \cdot d\vec{\ell} = q\vec{E} \cdot d\vec{\ell}$$

$$dU_q = -dW = -q\vec{E} \cdot d\vec{\ell}$$

Define

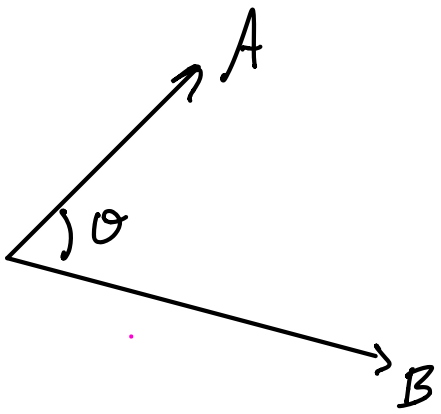
$$dV \equiv \frac{dU_q}{q} = -\vec{E} \cdot d\vec{\ell}$$

Electric Potential

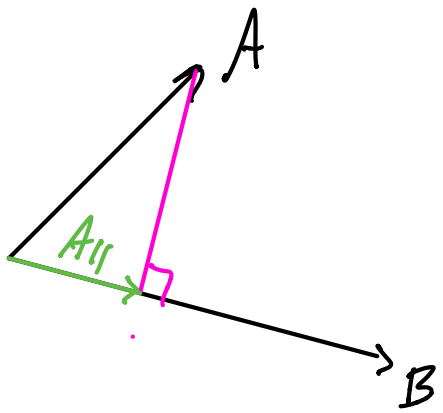
So $dU = q\,dV$

units of $[V] = \left[\frac{U}{q}\right] = \frac{J}{C}$ = Volt

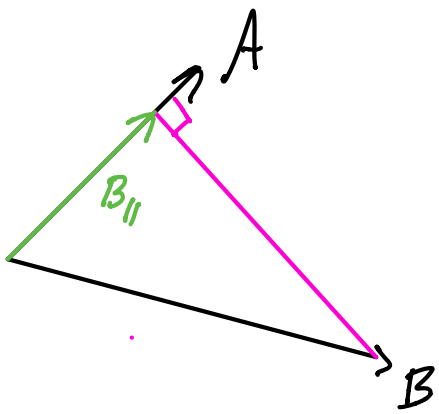
Recall:



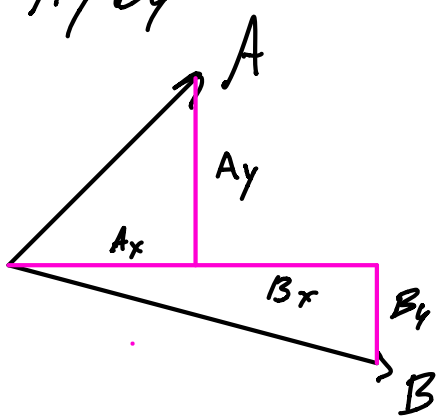
$$\vec{A} \cdot \vec{B} = A_{\parallel} B$$



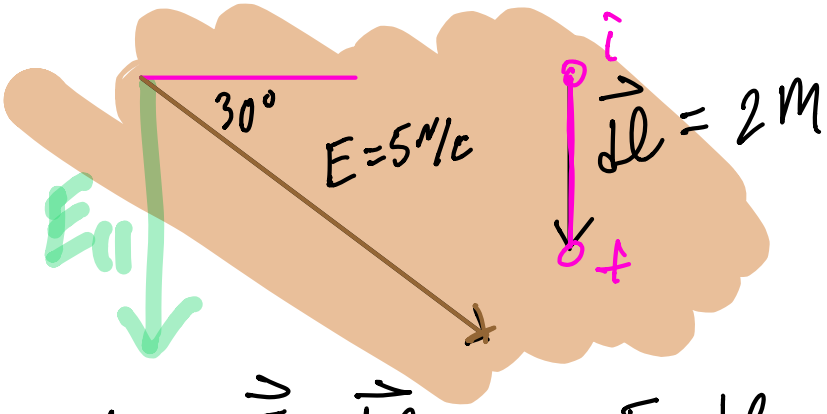
$$= A B_{\parallel}$$



$$= A_x B_x + A_y B_y$$

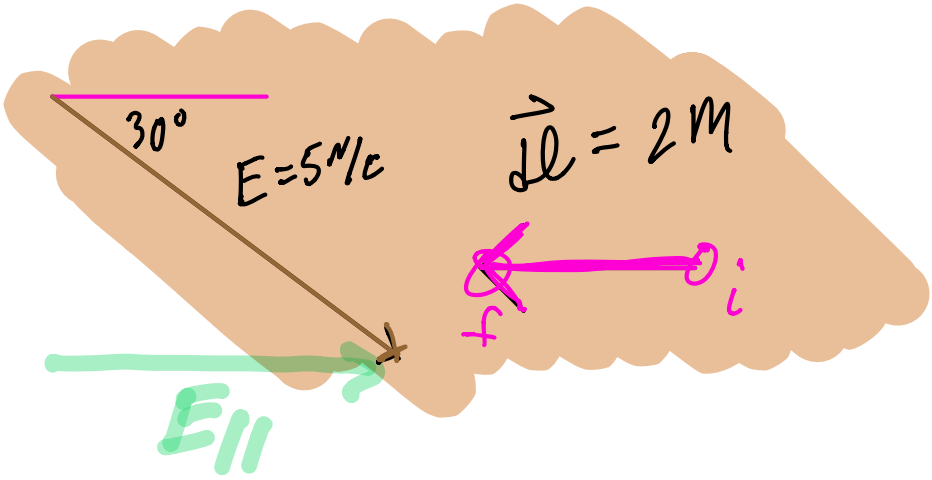


$$= AB \cos\theta$$



$$\Delta V = -\vec{E}\cdot\vec{dl} = -E_{11}\,dl$$

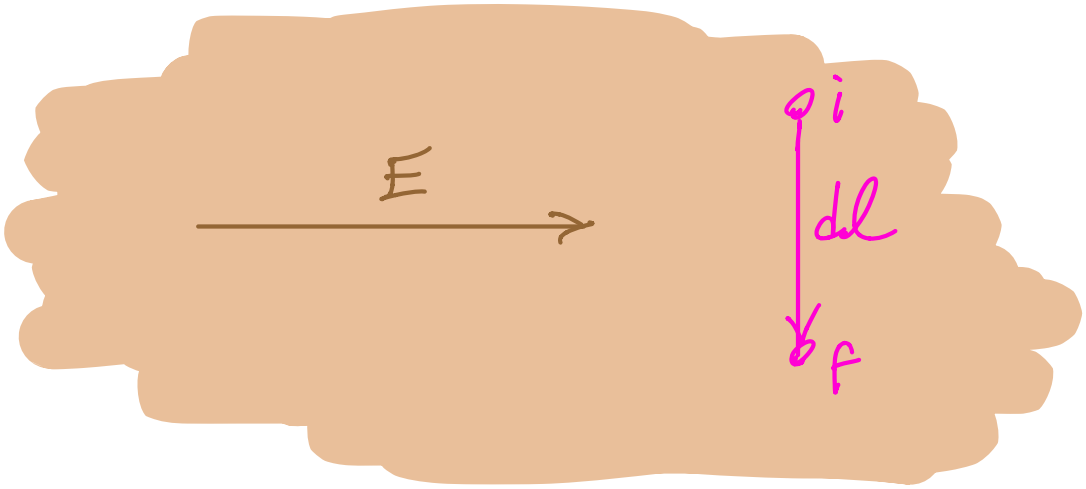
$$= -\left(\tfrac{1}{2}\,5\tfrac{N}{C}\right)(2m) = -5V$$



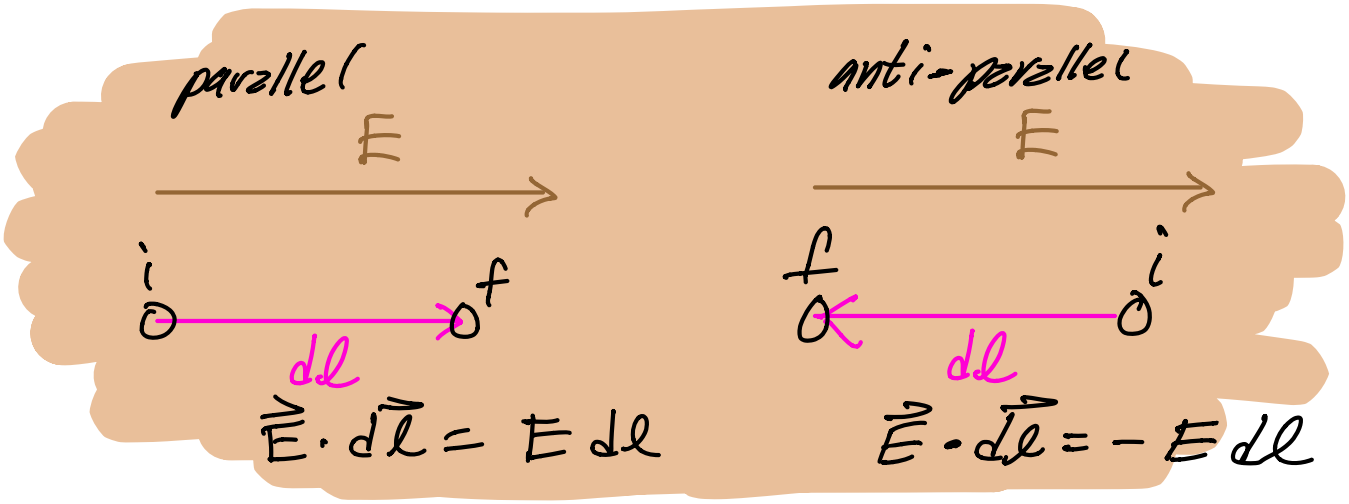
$$\Delta V = -\vec{E}\cdot\vec{dl} = -E_{11}\,dl$$

$$-\left(-\tfrac{\sqrt{3}}{2}\,5\tfrac{N}{C}\right)(2m) = 8.7\ V$$

Special Directions



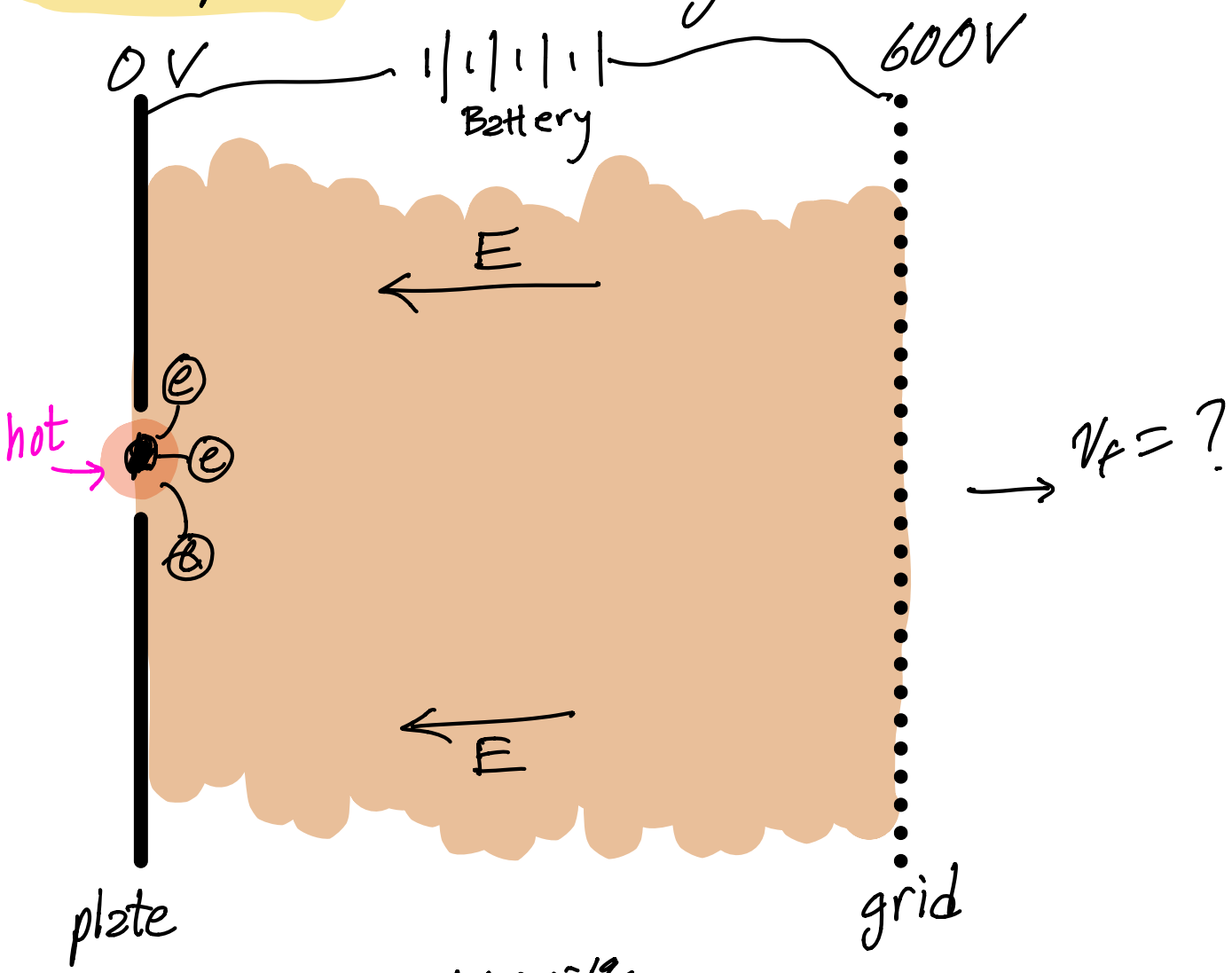
$$\Delta V = -\vec{E} \cdot d\vec{\ell} = 0$$



$$\Delta V = -\vec{E} \cdot d\vec{\ell}$$
$$= -E\,d\ell$$
$$E = -\frac{\Delta V}{d\ell}$$

$$\Delta V = -\vec{E} \cdot d\vec{\ell}$$
$$= E\,d\ell$$
$$E = \frac{\Delta V}{d\ell}$$

Example: electron "gun"



$q = -e = -1.6 \times 10^{-19} C$

$m_e = 9.11 \times 10^{-31} kg$

$\Rightarrow \quad \frac{e}{m_e} = 176 \times 10^9 \frac{C}{kg}$

1.76×10^{11}

$\Delta K + \Delta U = 0$

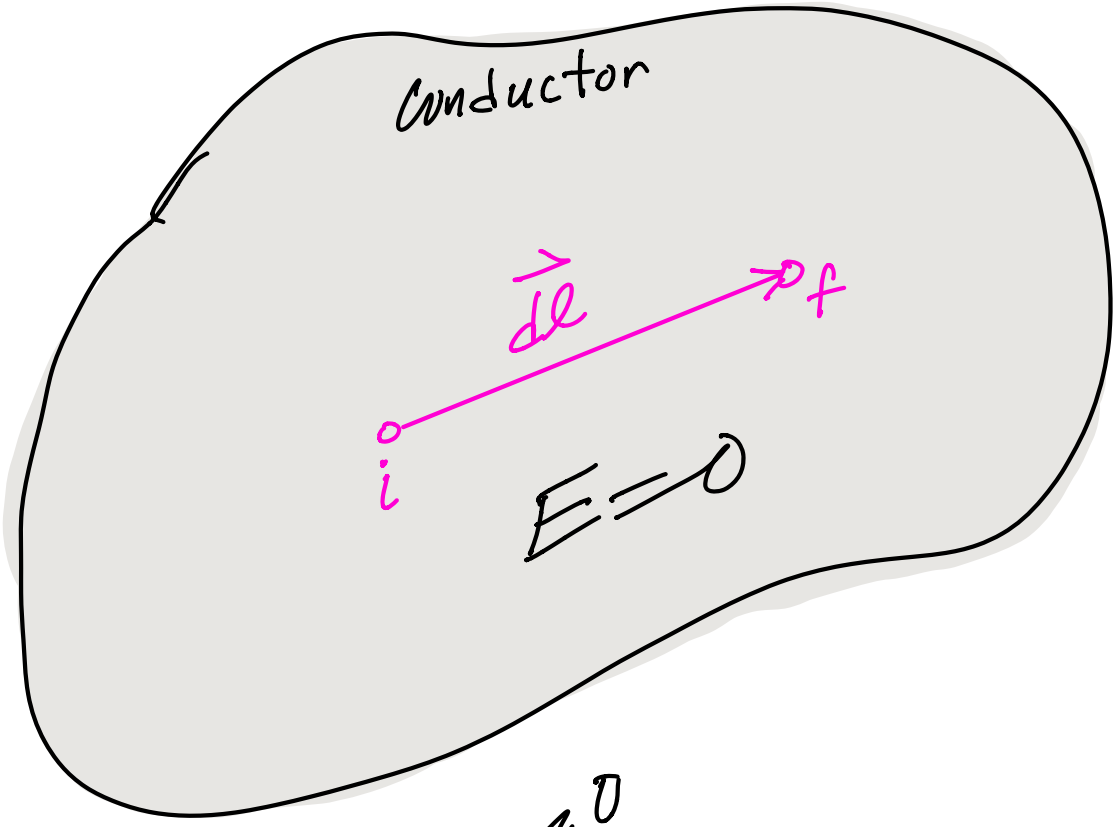
$\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 + q \Delta V = 0 \quad ; \quad \Delta V = V_f - V_i = 600V$

($\frac{1}{2} m v_i^2 \to 0$)

$v_f = \sqrt{-2 \frac{q}{m} \Delta V}$

$= \sqrt{2 \frac{e}{m} \Delta V} = 14.5 \times 10^6 \, m/s$

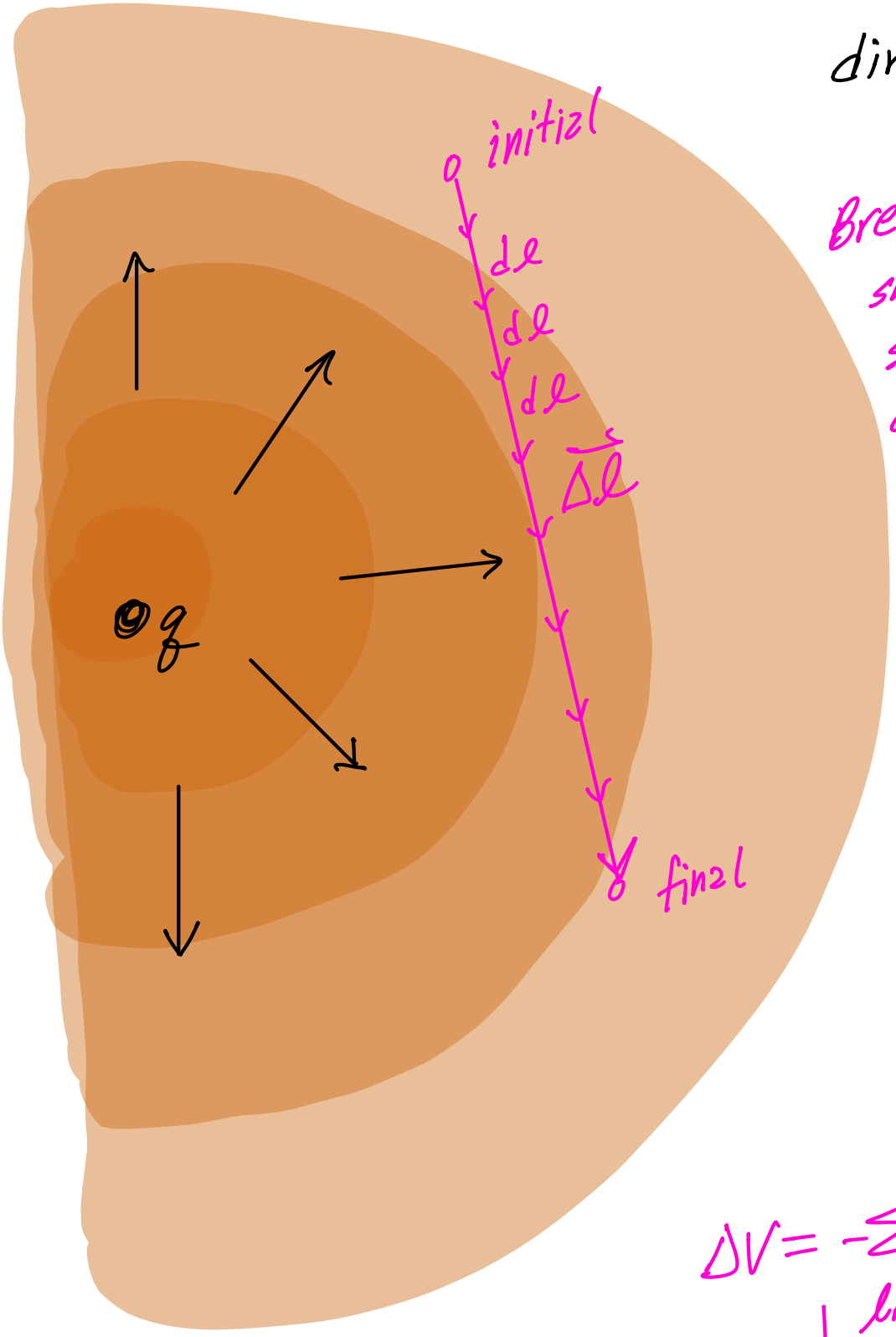
Electric Potential Inside a Conductor



$$\Delta V = -\cancel{\vec{E} \cdot d\vec{l}}^{\,0} = 0$$

Nonuniform field

$\vec{E}$ either changing magnitude or direction



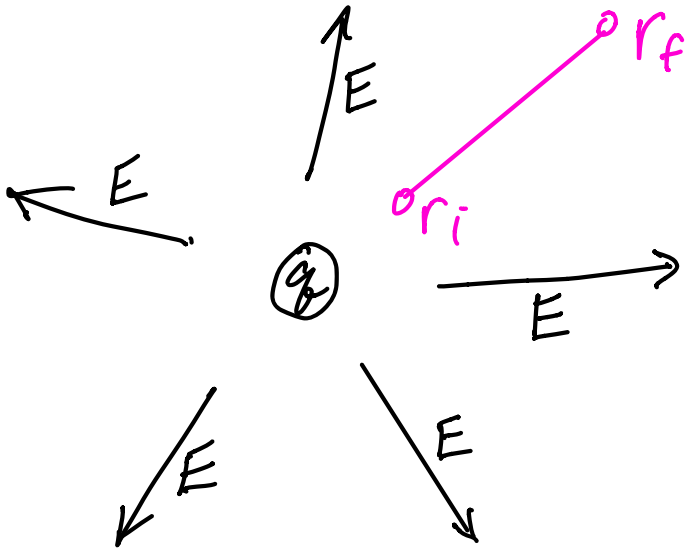
Break path into small sub-paths $\vec{d\ell}$ so that $\vec{E}$ is ≈ constant over each subpath.

$$\Delta V = -\sum \vec{E} \cdot \vec{d\ell}$$

$$\downarrow \lim d\ell \to 0$$

Use $$\Delta V = -\int_i^f \vec{E} \cdot \vec{d\ell}$$

Electric Potential Due to a Point Charge



$$E = k\frac{q}{r^2}$$

$$\Delta V = -\int_{r_i}^{r_f} \vec{E} \cdot \vec{dl}$$

$$= -\int_{r_i}^{r_f} E \, dl$$

$$= -\int_{r_i}^{r_f} k\frac{q}{r^2} dr$$

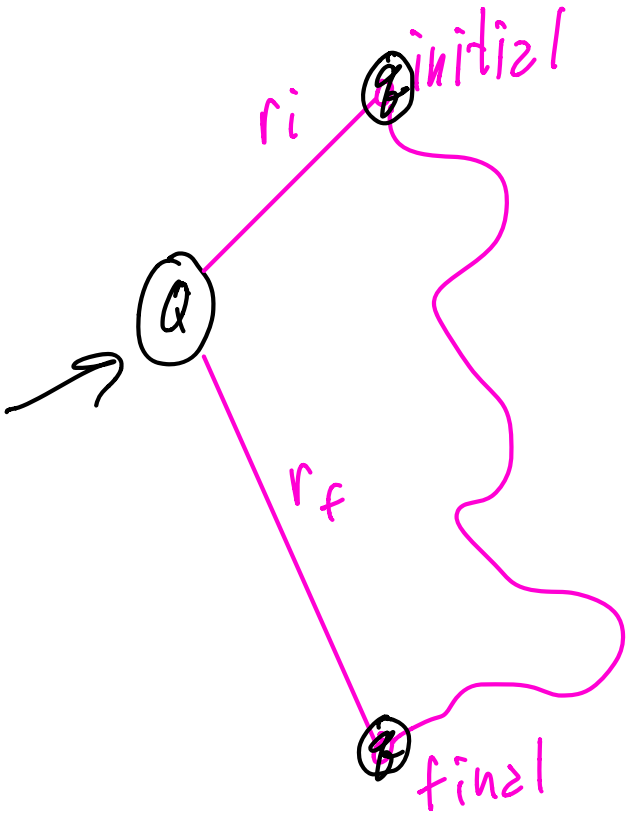
$$= \left[k\frac{q}{r} \right]_{r_i}^{r_f}$$

$$= k\frac{q}{r_f} - k\frac{q}{r_i}$$

$$= V(r_f) - V(r_i)$$

$$V(r) = k\frac{q}{r}$$

Ex



given

$Q = 4nC$

$r_i = 2.0m$

$r_f = 3.0m$

$v_i = 10 m/s$

$\frac{q}{m} = \frac{22}{6} \frac{C}{kg}$

$v_f = ?$

$$\Delta K + \Delta U = 0$$

$$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 + q\Delta V = 0$$

$$v_f^2 = v_i^2 - 2\frac{q}{m}\Delta V$$

$$v_f^2 = v_i^2 - 2\frac{q}{m}\left(k\frac{Q}{r_f} - k\frac{Q}{r_i}\right)$$

$$= v_i^2 - 2\frac{q}{m}kQ\left(\frac{1}{3m} - \frac{1}{2m}\right)$$

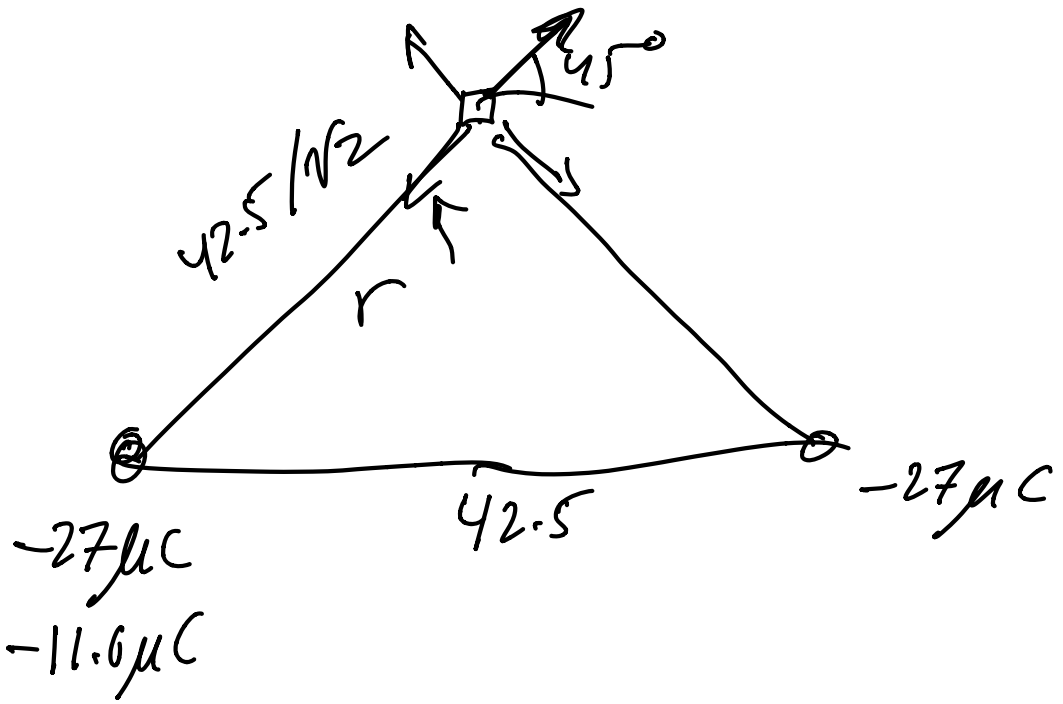
$$= 144 \frac{m^2}{s^2}$$

$$v_f = 12 m/s$$

30. (II) Calculate the electric field at the center of a square 42.5 cm on a side if one corner is occupied by a $-38.6\,\mu C$ charge and the other three are occupied by $-27.0\,\mu C$ charges.

$-27\mu C$

0 $\quad$ 0 $\quad$ $-27\mu C$



$$E = k\frac{q}{r^2} = k\frac{11.6\mu C}{42.5^2/2}$$

$$\begin{array}{r} 27.0 \\ +11.6 \\ \hline 38.6 \end{array}$$

50. Estimate the net force between the CO group and the HN group shown in Fig. 16–63. The C and O have charges $\pm 0.40e$, and the H and N have charges $\pm 0.20e$, where $e = 1.6 \times 10^{-19}$ C. [*Hint*: Do not include the "internal" forces between C and O, or between H and N.]

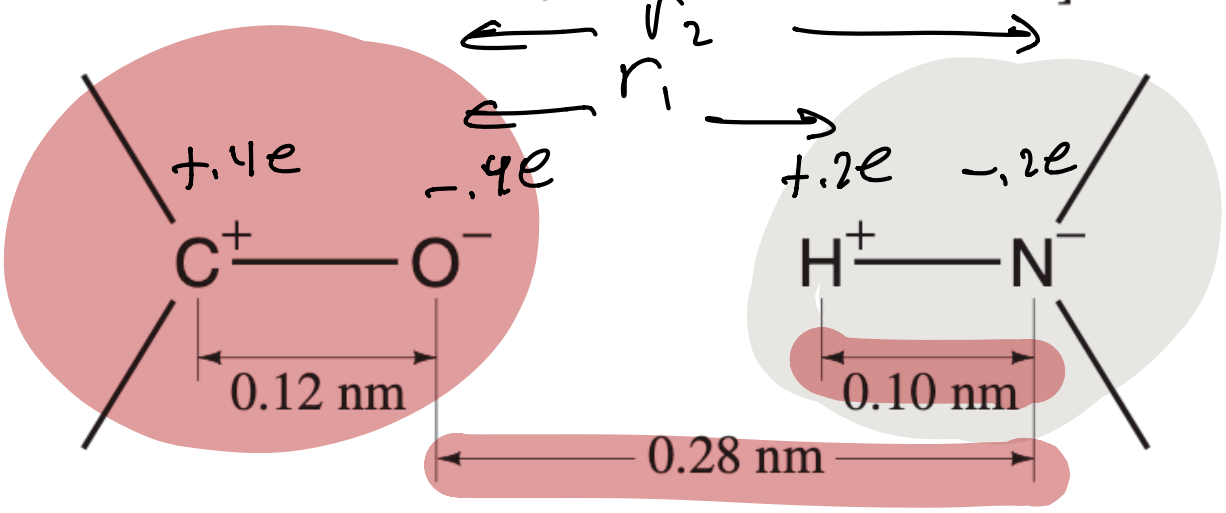


FIGURE 16–63 Problem 50.

r_2

r_1

r_3

r_4

$F_1 \rightarrow +$

$F_2 \leftarrow -$

$F_3 \leftarrow -$

$F_4 \rightarrow +$

$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4$

$F = F_1 - F_2 - F_3 + F_4$

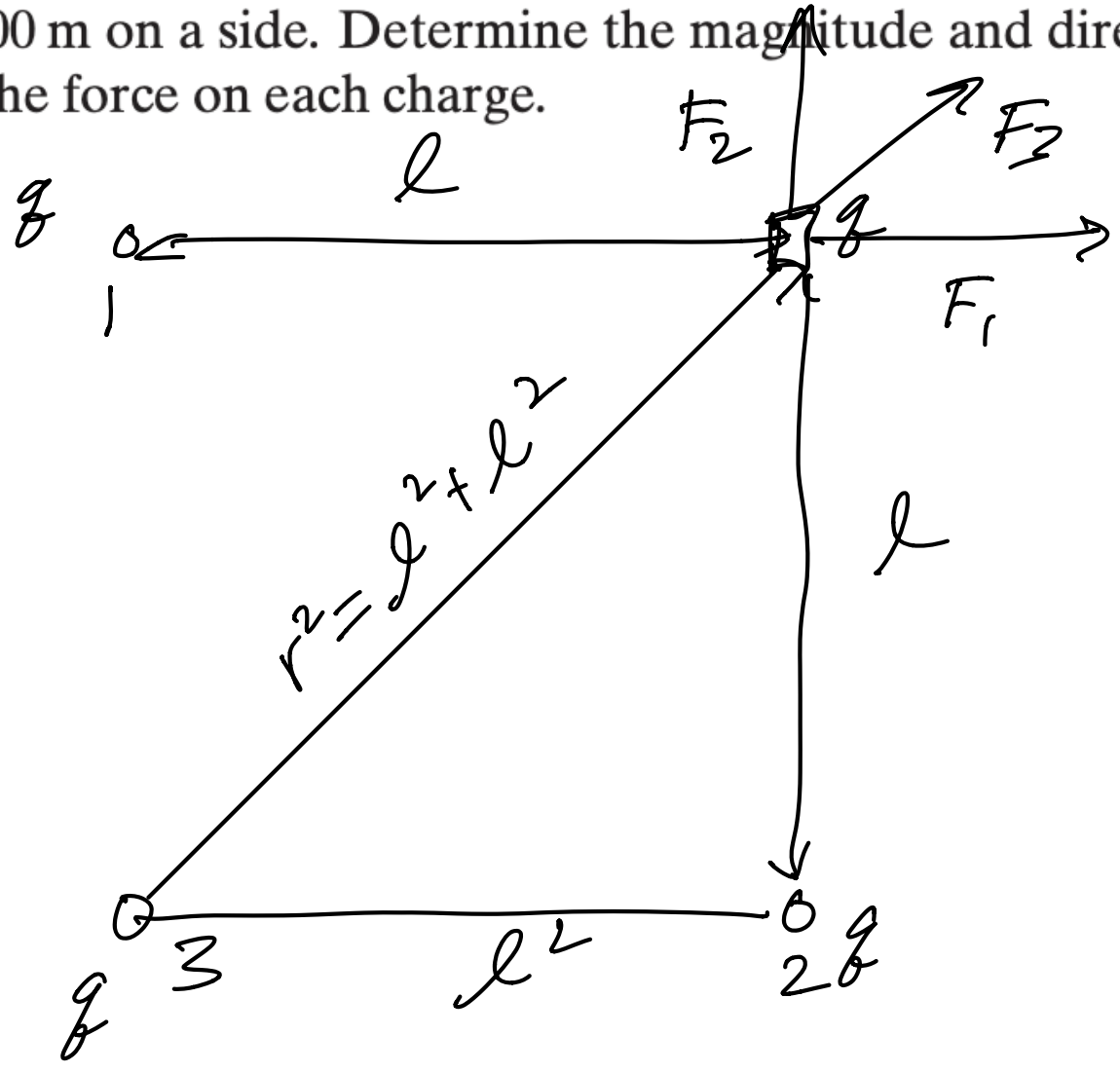
$r_1 = (0.28 - 0.10)\ \text{nm}$

$r_2 = 0.28\ \text{nm}$

$r_3 = 0.12\ \text{nm} + r_1$

$r_4 = 0.12\ \text{nm} + 0.28\ \text{nm}$

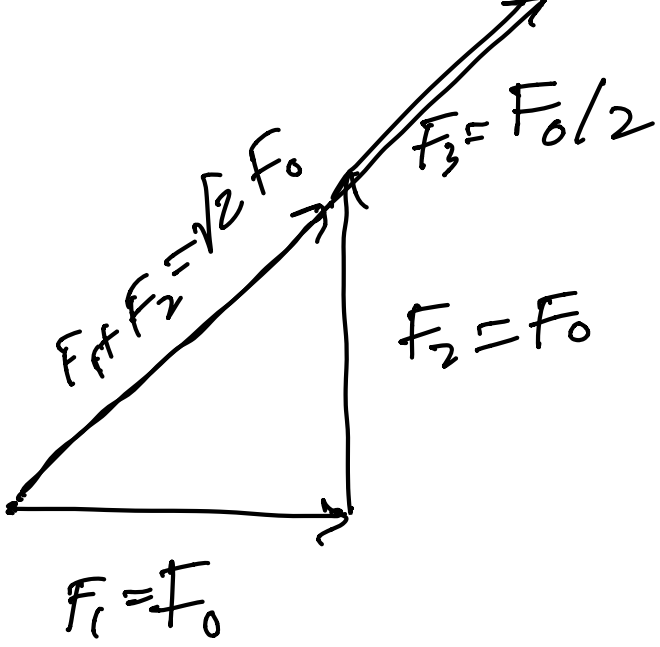
14. (II) A charge of 6.15 mC is placed at each corner of a square 0.100 m on a side. Determine the magnitude and direction of the force on each charge.

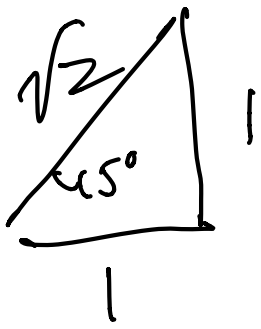


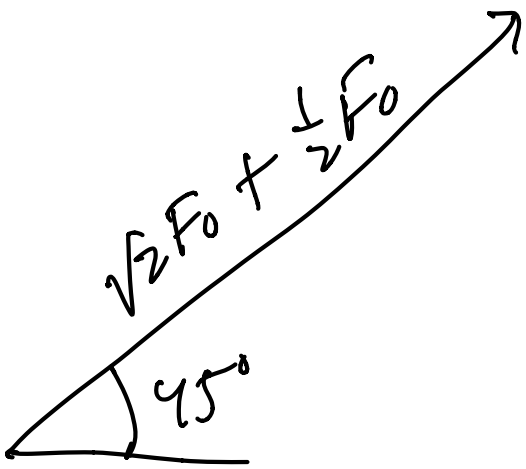
$$F_1 = k\frac{qq}{l^2} = F_0$$

$$F_2 = F_0$$

$$F_3 = k\frac{qq}{l^2+l^2} = \frac{1}{2}k\frac{qq}{l^2} = \frac{1}{2}F_0$$







$$F = \left(\sqrt{2} + \frac{1}{2}\right) F_0$$