WEDNESDAY, 25 January → In-Class quiz

EX 100 OR EX 200

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# CHAPTER 18:

18.1: A MODEL OF THE MECHANISM FOR ELECTROSTATIC INTERACTIONS

18.2: SKILLS OF ANALYZING PROCESSES INVOLVING E-FIELDS

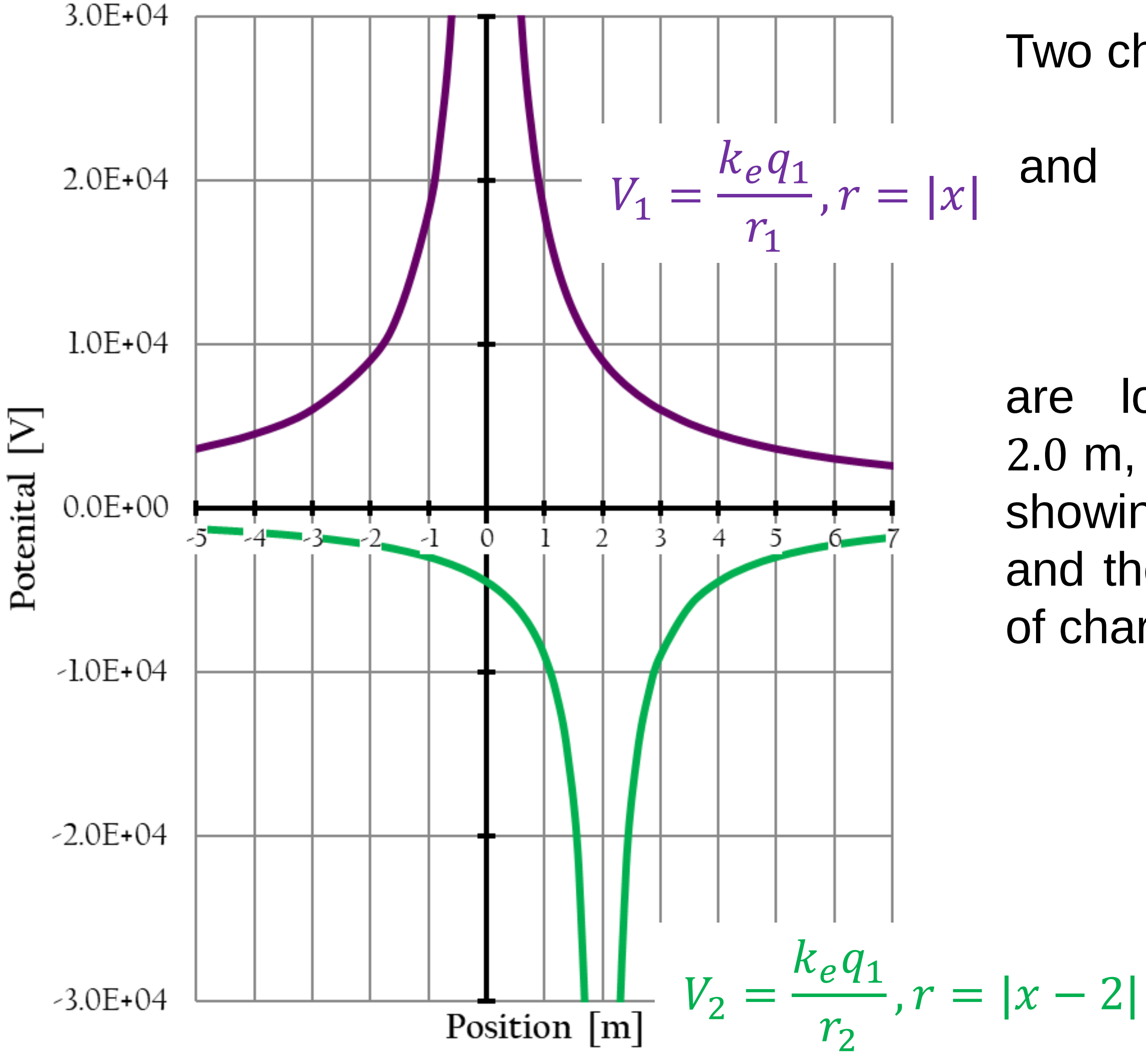
18.3: THE V-FIELD: ELECTRIC POTENTIAL

**18.4: RELATING THE E-FIELD AND THE V-FIELD**

17.4: COULOMB'S FORCE LAW

17.5: ELECTRIC POTENTIAL ENERGY

# Visualizing the Electric Potential




Two charges,

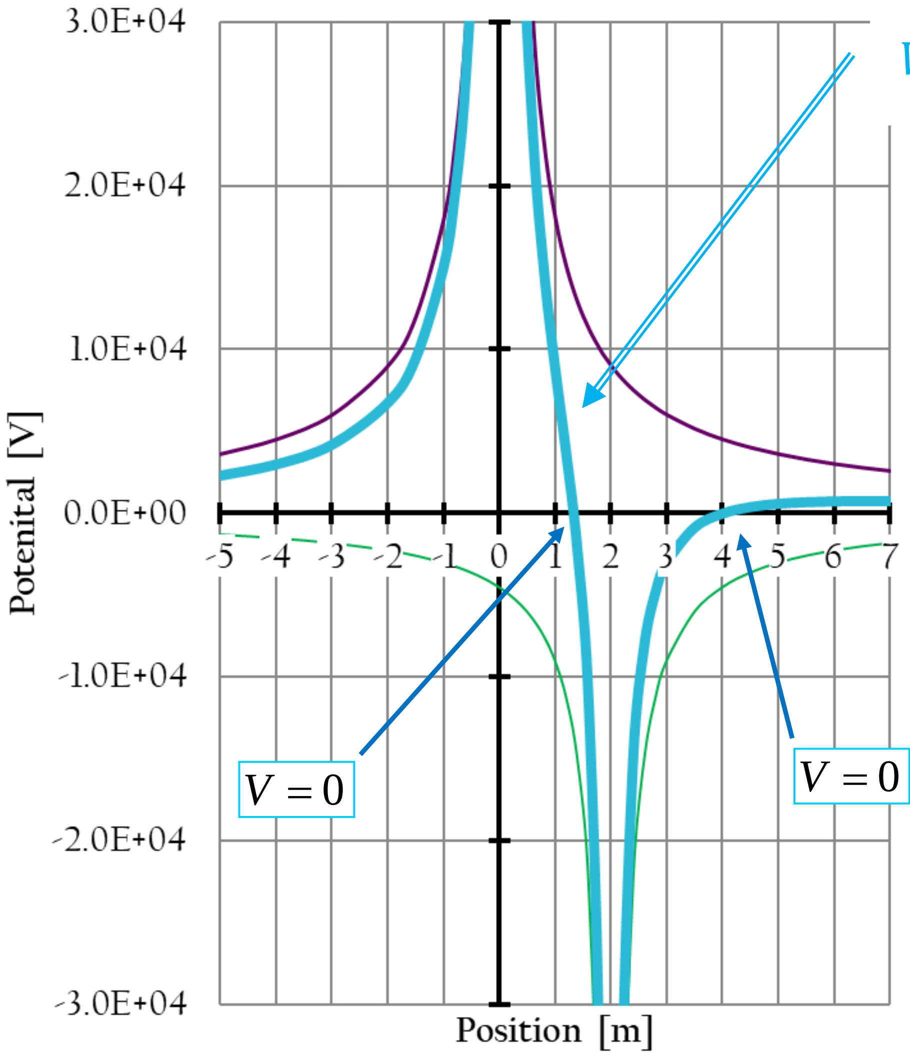
$$q_1 = +2.0\ \mu C$$

and

$$q_2 = -1.0\ \mu C$$

are located at $x_1 = 0.0$ m and $x_2 = 2.0$ m, respectively. Sketch a graph showing potential due to each charge and the total potential for the system of charges.

# VISUALIZING THE ELECTRIC POTENTIAL




$$V_{TOTAL} = V_1 + V_2 = \frac{k_e q_1}{|x|} + \frac{k_e q_2}{|x-2|}$$

Two charges,

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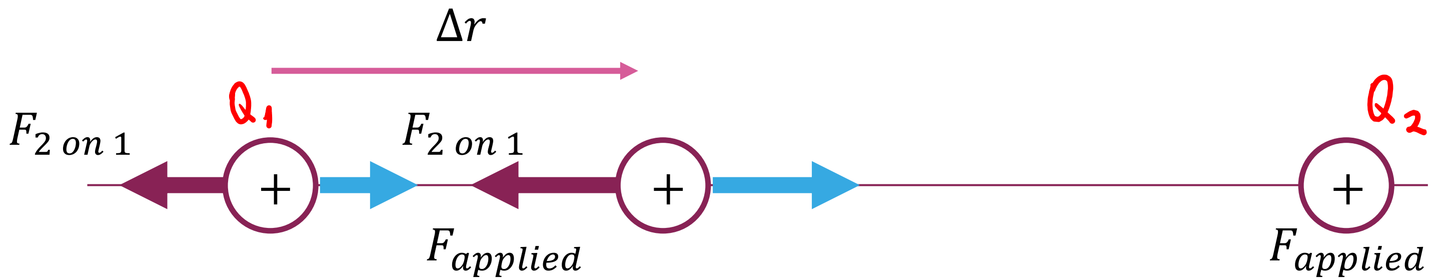
are located at $x_1 = 0.0$ m and $x_2 = 2.0$ m, respectively. Sketch a graph showing potential due to each charge and the total potential for the system of charges.

$$V_1 = \frac{k_e q_1}{r_1}, r = |x| \qquad V_2 = \frac{k_e q_1}{r_2}, r = |x-2|$$

$$F_e = \frac{k_e Q_1 Q_2}{r_{12}^2} \qquad\qquad U = \frac{k_e Q_1 Q_2}{r_{12}}$$

When external force does work moving one charge in the presence of another, it changes the energy of the two-charge system.

If the force matches the electric force then $W_{F_{applied}} = -W_{F_e} = \Delta U_q$




Source charges also create **electric field:**

$$\vec{E}_Q = \frac{\vec{F}_{Q\ on\ q}}{q} = \frac{k_e Q}{r^2}\hat{r}$$

and **electric potential:**

$$V_Q = \frac{U_{of\ Q\ and\ q}}{q} = \frac{k_e Q}{r}$$

# CONNECTING POTENTIAL AND FIELD

Recall that for the conservative forces we can always connect work done by electric force on the charge and the change in charge's potential energy.
In a uniform electric field

$$\Delta U_q = -W_{F_e} = -F_e \Delta r \cos\theta$$

Using the definitions of electric field $E = \frac{F}{q}$ and electric potential $\Delta V = \frac{\Delta U}{q}$ we can see that potential between two points is

$$\Delta V = -E\Delta r\, cos\theta$$

*For a known electric field, generally, potential change between two points is:

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

$\vec{E}$ is a function of position ∴ we would need to integrate. WE WON'T!

Which, for **uniform electric field** simplifies to: $\Delta V = -\int_i^f \vec{E} \cdot d\vec{s} = -E_s \Delta s$

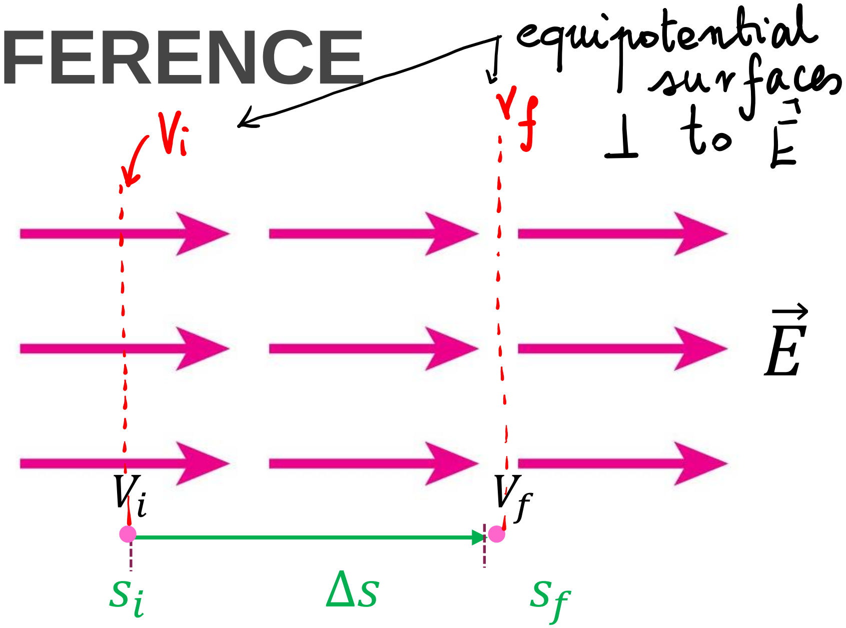
Means the electric potential is DECREASING
in the direction of the electric field!

# POTENTIAL DIFFERENCE

For a uniform electric field:

$\Delta V$ simplifies to

$$\Delta V = -E_s \Delta s$$




The potential difference $\Delta V$ between any two points is

$$\begin{aligned} \Delta V &= V_f - V_i \\ &= -\left(E s_f - E s_i\right) \\ &= -E\left(s_f - s_i\right) \\ &= -E \Delta s \end{aligned}$$

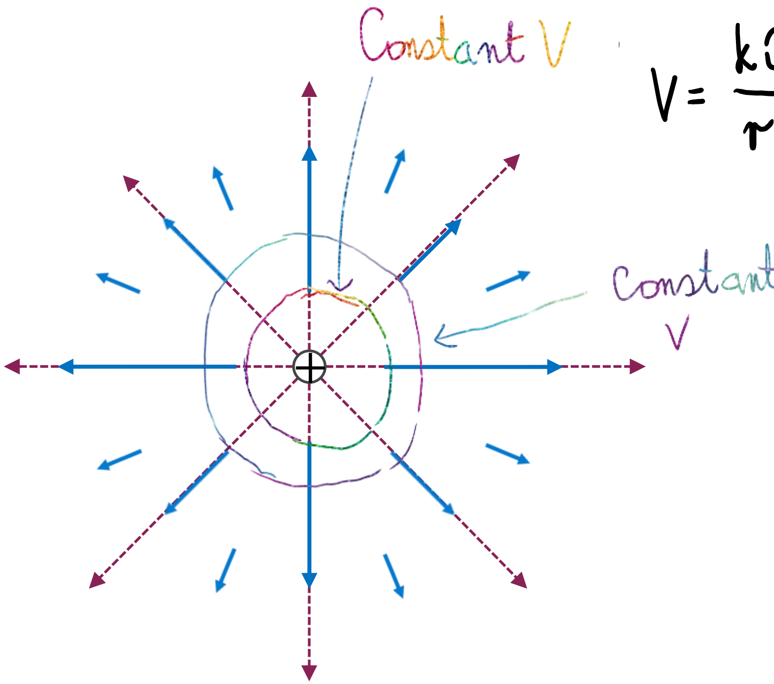
The electric field $E$ is:

$$E = -\frac{\Delta V}{\Delta s}$$ → V decreases along $\vec{E}$

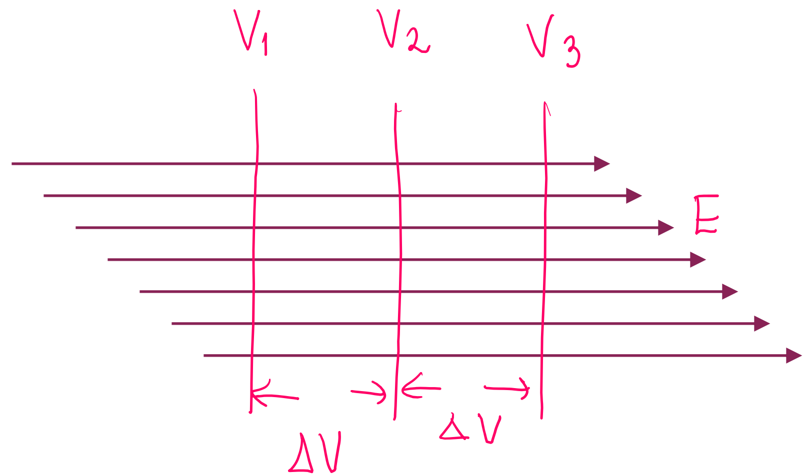
Units of $E$ can be expressed as:

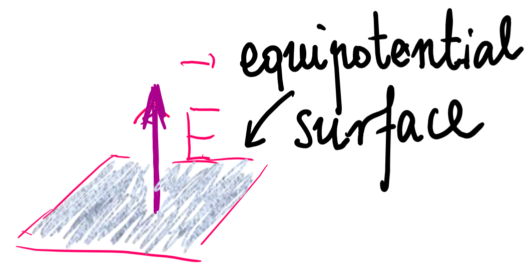
$$\frac{\mathrm{N}}{\mathrm{C}} \quad \text{or} \quad \frac{\mathrm{V}}{\mathrm{m}}$$

In two dimensions we draw **equipotential lines** perpendicular to the electric field:




$$V = \frac{kQ}{r}$$



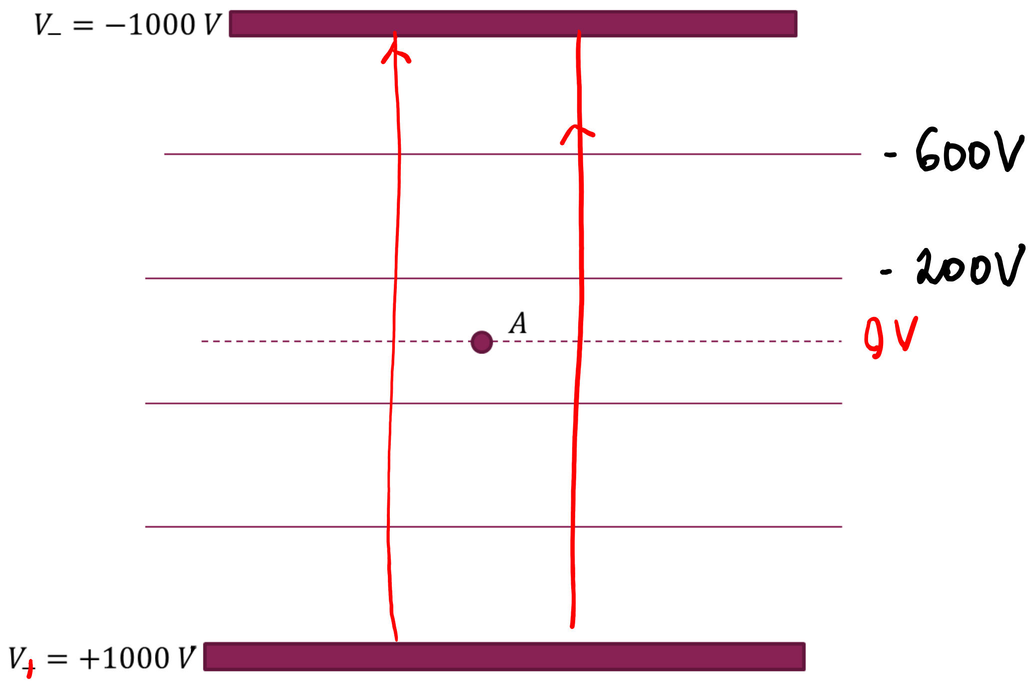




… but we need to think about them as existing in 3D.

So equipotential planes around a point charge are concentric shells, equipotential planes in uniform electric field are planes perpendicular to the field, etc.

# EXAMPLE 18F

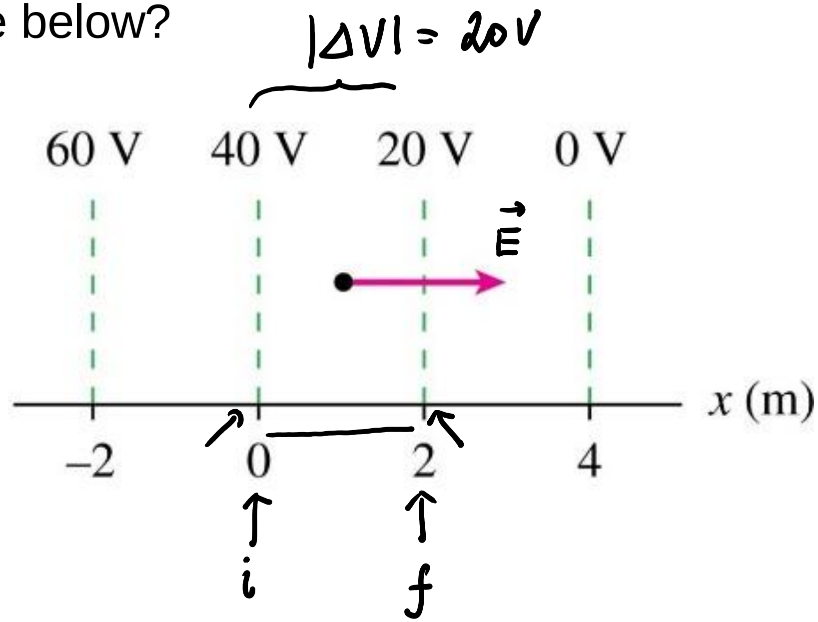
Dotted lines represent **equipotential lines** (lines along which electric potential is the same.)




What is the electric potential at point A?

# EXAMPLE 18D

What is the electric field at the dot in the figure below?




$|\Delta s| = 2.0\,m$

$$\Delta V = -E_s \Delta s$$

METHOD #I

I. $|E_s| = \dfrac{|\Delta V|}{|\Delta s|}$

$$|E_s| = \frac{20V}{2.0m} = 10\,\frac{V}{m}$$

in $+x$ dir

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METHOD #II

II. $\Delta V = -E_s \Delta s = -E_x (x_f - x_i)$

$$V_f - V_i = -E_x (x_f - x_i)$$

$$V(2) - V(0) = -E_x (2 - 0)$$

$$20 - 40 = -2E_x$$

$$-20V = -2E_x \rightarrow E_x = 10\,\frac{V}{m}$$

# EXAMPLE 18E

only movement along $E$ matters

In a certain region electric field is equal to $150\ \mathrm{N/C}$ and point in $+x$ direction.

Electric potential at point $A = (-1.0\ \mathrm{m}, +1.0\mathrm{m})$ is measured to be $-750\ \mathrm{V}$.

What is the electric potential at point $B = (+2.0\ \mathrm{m}, +2.0\mathrm{m})$?

METHOD I

a) $\Delta V = -E_x \Delta x$

$|\Delta V| = |E_x||\Delta x|$

$\Delta V = \left|150 \frac{N}{C}\right| \left|\underbrace{x_f - x_i}_{x_B - x_A}\right| = 150 \frac{N}{C} \cdot |3| = 450V$

along $\vec{E}$ field so $V_B = V_A - 450V$

$= -1200V$

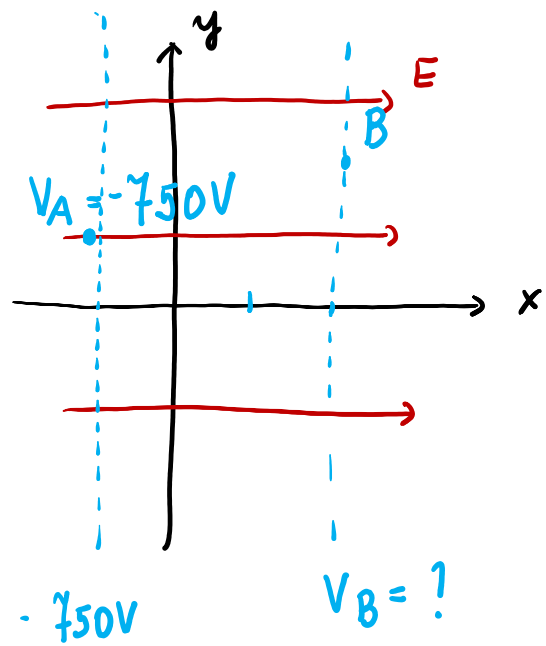
METHOD II

b) $\Delta V = -E_x \Delta x$

$V_B - V_A = -E_x (x_B - x_A) = -(150)(+2 - (-1))$

$V_B - (-750) = -450\ V$

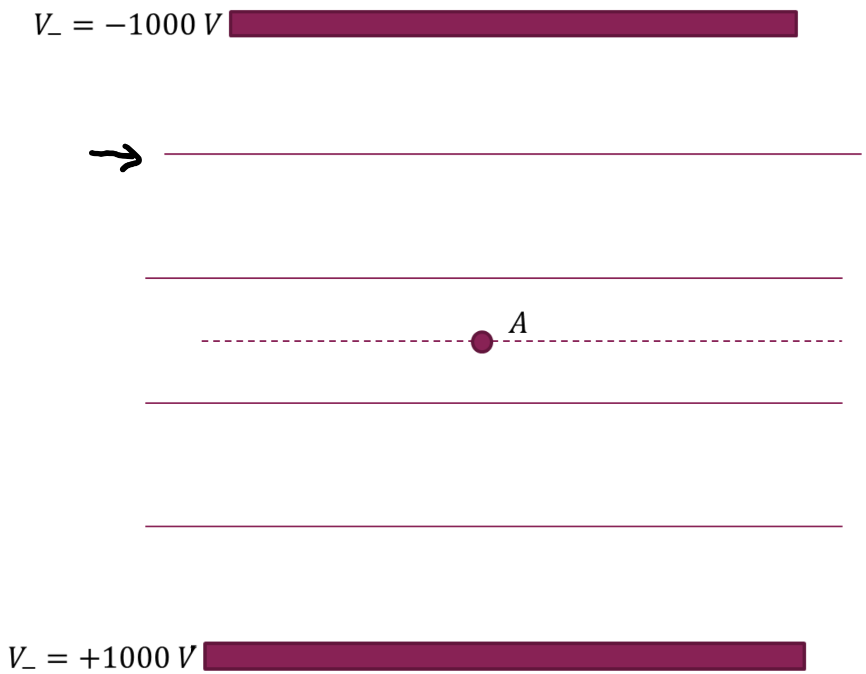
$V_B + 750 = -450V \rightarrow V_B = -1200V$




you "lose" $|E|$ Volts every meter along dir. $\vec{E}$

# EXAMPLE 18F

Dotted lines represent **equipotential lines** (lines along which electric potential is the same.)




What is the electric potential at point A?

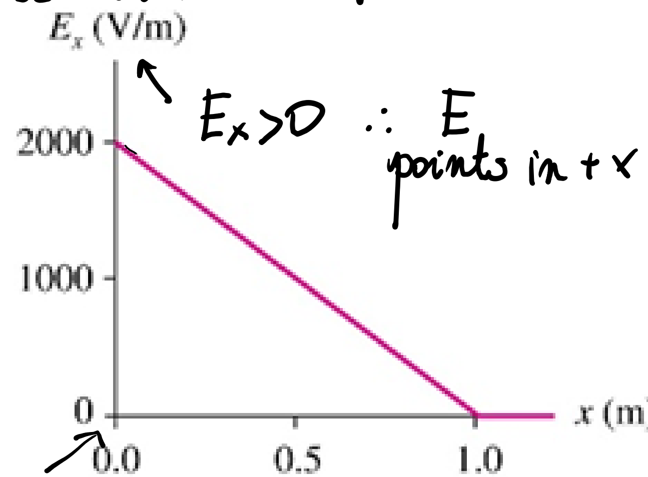
NOT EASY!! (A+ level!)

# EXAMPLE 18G*

← * = "NINJA QUESTION"

≡ you have the tools but it takes them all!

The following is a graph of the *x*-component of the electric field along the *x*-axis. The potential is zero at the origin. What is the potential at *x* = 1 m?




$E_x > 0$ ∴ E points in +x

V = 0

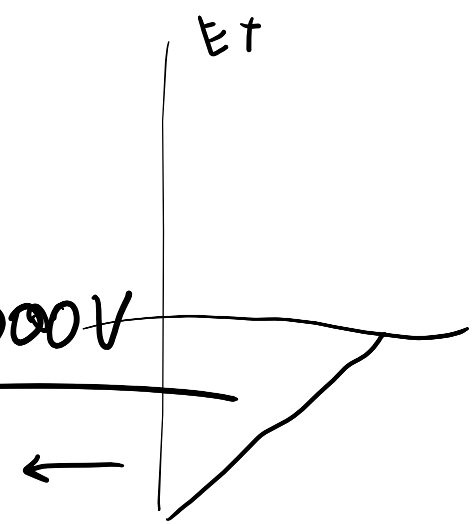
$\Delta V = -E_x \Delta x$

$\Delta V = -$ area under $E_x(x)$ graph!

$\Delta V = -\frac{1}{2} \cdot 2000 \cdot 1 = -1000\ V$

$\Delta V = V(1) - V(0) = V(1) - 0$

$V(1) = -1000\,V$



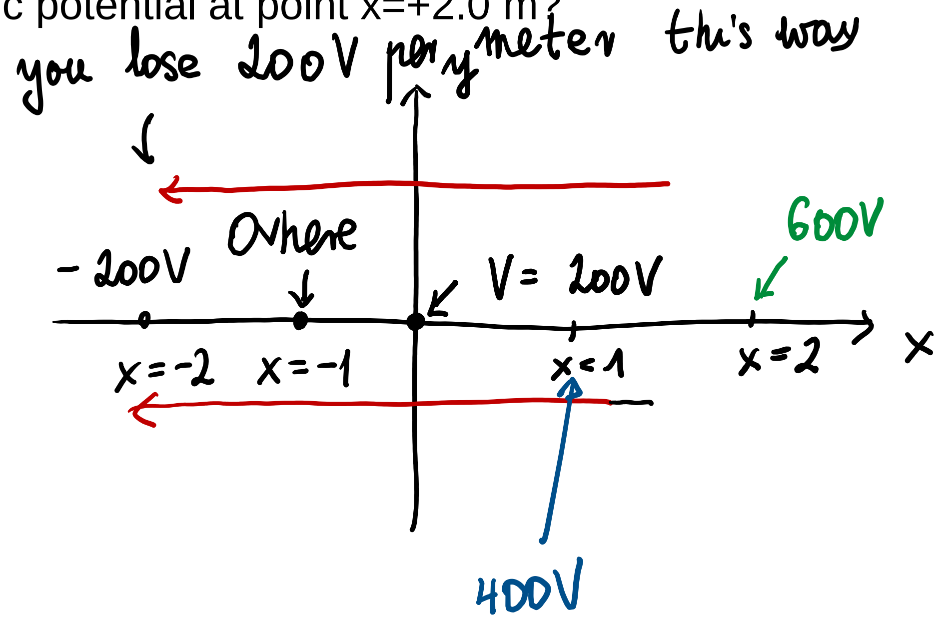
# Example

Electric potential at the origin is measured to be 200 V.

The electric field in the region points in –x direction and has a magnitude of 200 N/C.

brave person!

What is the electric potential at point x=+2.0 m?




$|\Delta V| = |-E_s \cdot \Delta s|$

$= +200 \cdot (2-0)$

$= 400$

since against field

$400 + 200 = 600$

OR: $\Delta V = -E_x \Delta x$

$= -(\underset{\text{neg } x}{-}200) \cdot (\underset{2m}{x_f} - \overset{0m}{x_i}) = -(-200 \frac{V}{m}) \cdot (2m)$

$\rightarrow \Delta V = V(2) - V(0)$

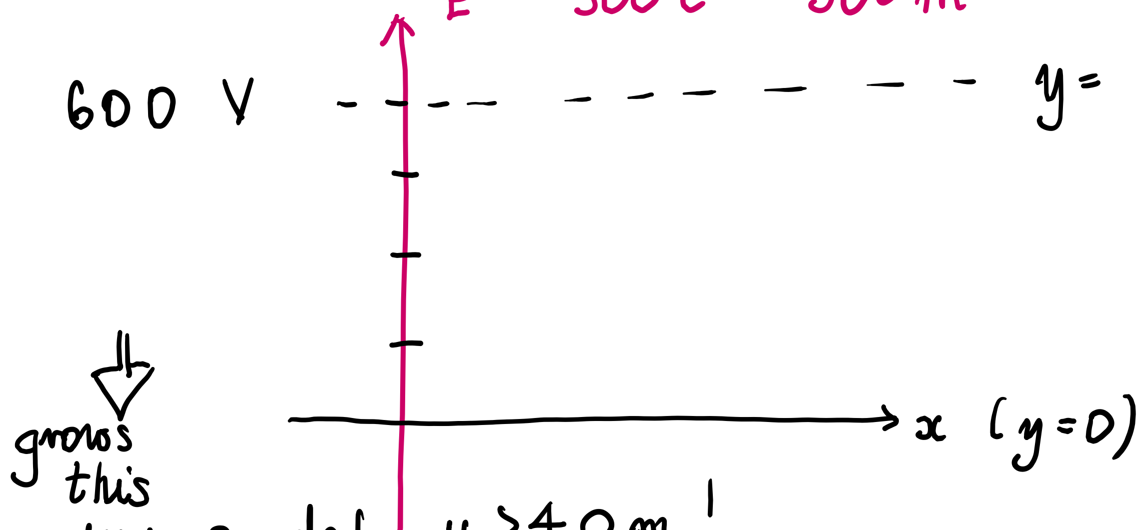
# EXAMPLE

In certain region the electric field points in +y direction and has magnitude of 300 N/C.

At point y=4.0 m the electric potential is equal to +600 V.

At what point along y axis will the electric potential be zero?
Provide your answer in meters, rounded to an integer. Do not include unitsi in your answer.

$E = 300 \frac{N}{C} = 300 \frac{V}{m}$




so def. $y > 4.0$ m !

looking for · know · look for · know

$$\Delta V = V_f - V_i = 0 - 600 = -(300)(y_f - 4.0)$$

know