Potential Energy

Scott N. Walck

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Two kinds of potential energy from Physics 103

- Gravitational potential energy

$$\mathrm{PE} = mgy = mgh$$

- Elastic potential energy (spring potential energy)

$$\mathrm{PE} = \frac{1}{2}kx^2$$

In both cases, force points in the direction of decreasing potential energy.

Electric potential energy in old electricity theory

$$\mathrm{PE} = k\frac{qQ}{r}$$

- Two positive charges have more potential energy when they are close together than when they are far apart.
- Two negative charges have more potential energy when they are close together than when they are far apart.
- Unlike charges have less potential energy when they are close together than when they are far apart.

Force points in the direction of decreasing potential energy.

Conservative and nonconservative forces

Force	Conservative?	Potential Energy
Gravity	Conservative	$\mathrm{PE} = mgy$
Normal Force	Nonconservative	none
Rope Tension	Nonconservative	none
Friction	Nonconservative	none
Spring	Conservative	$\mathrm{PE} = \frac{1}{2}kx^2$
Electric	Conservative	$\mathrm{PE} = k\frac{qQ}{r}$

- k in spring potential energy is spring constant
- k in electric potential energy is electric constant

We really only care about *differences* in PE.

- Zero PE has no special meaning.
- We never talk about the magnitude of PE.
- PE can be negative. This negative does not indicate a direction. It means a lower PE than zero.

Electric potential energy in the new electromagnetic theory

- Electric Potential $\neq$ Electric Potential Energy
- Aspect 1: Charge creates electric potential.
- Aspect 2: Electric potential invests charge with potential energy.

What is Electric Potential?

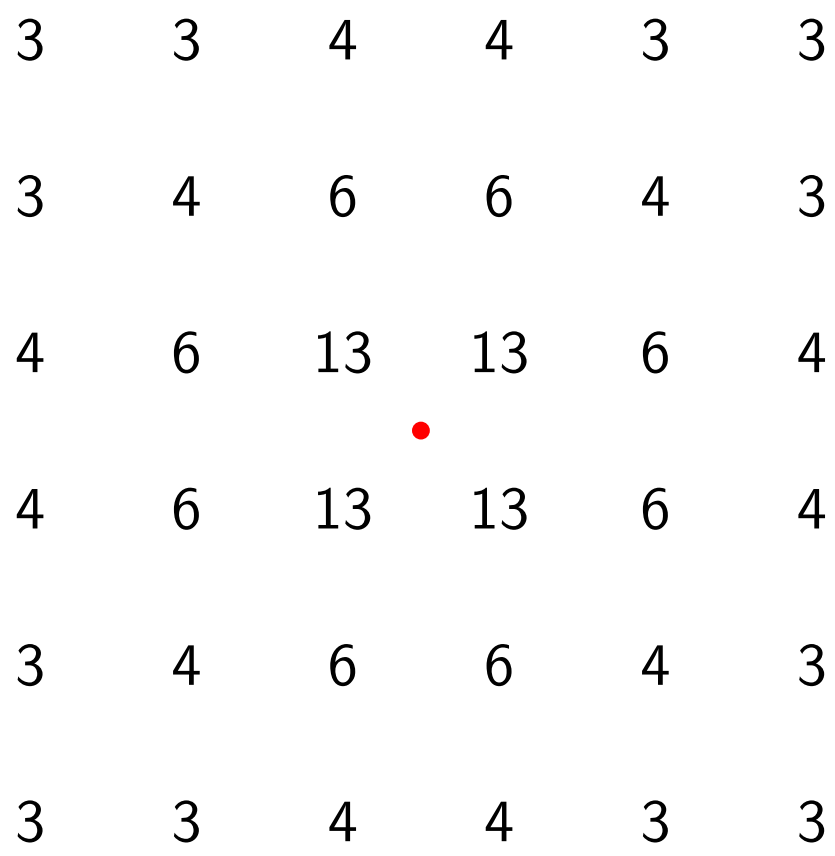
- Electric potential is something that permeates all space.
- Each point in space has a number for electric potential.
- Electric potential is a scalar field.
- Electric charge produces electric potential.
- Electric potential invests charge with potential energy.
- Electric potential can change in time, so it permeates all space-time.
- Electric field points in the direction of decreasing electric potential.
- Symbol: V
- SI Unit: Volt (V)

Electric potential produced by a charged particle

The electric potential produced by a particle with charge Q at a distance r from the particle is

$$V = k\frac{Q}{r}.$$

Electric potential produced by a positively charged particle

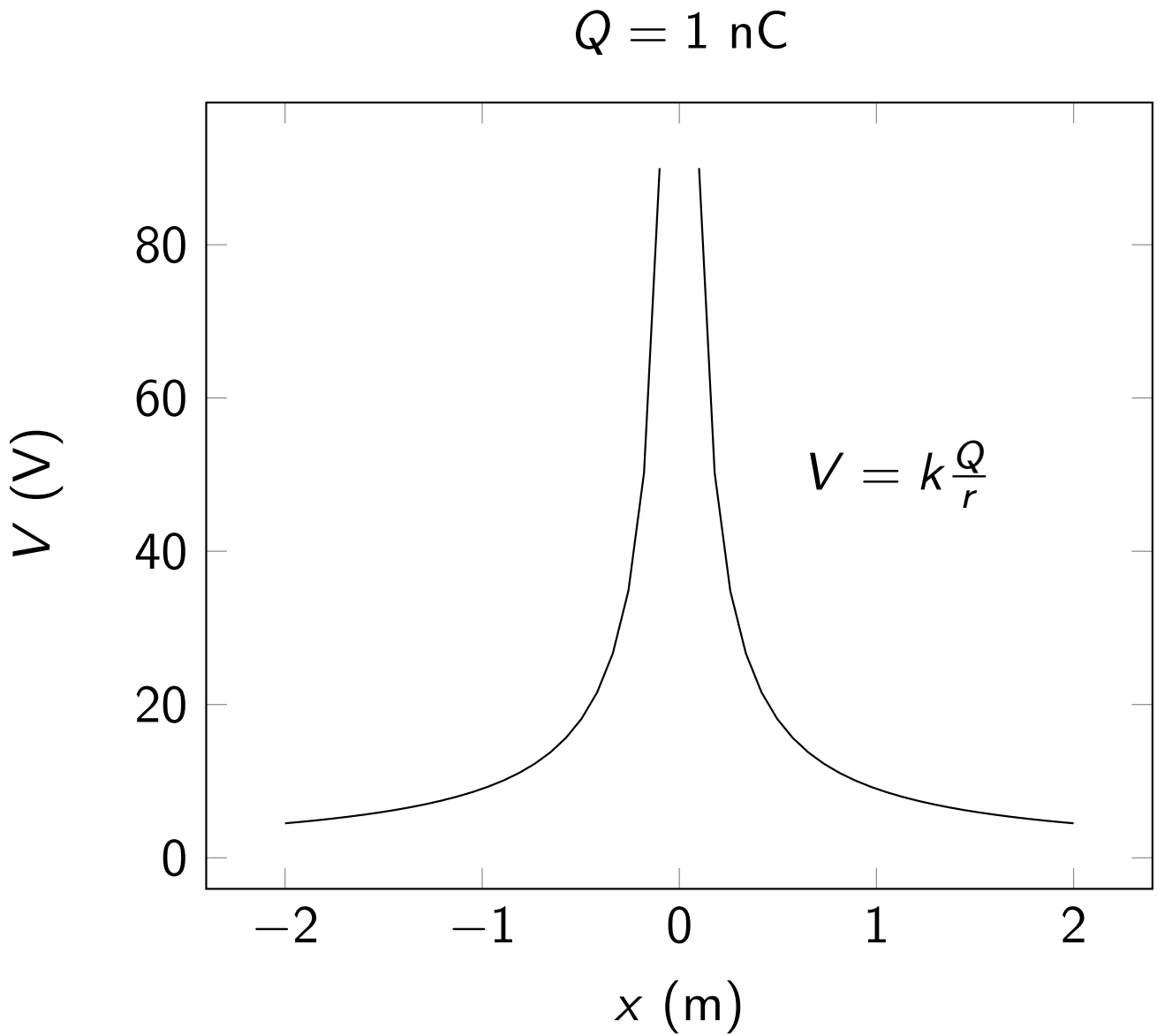


$Q > 0$

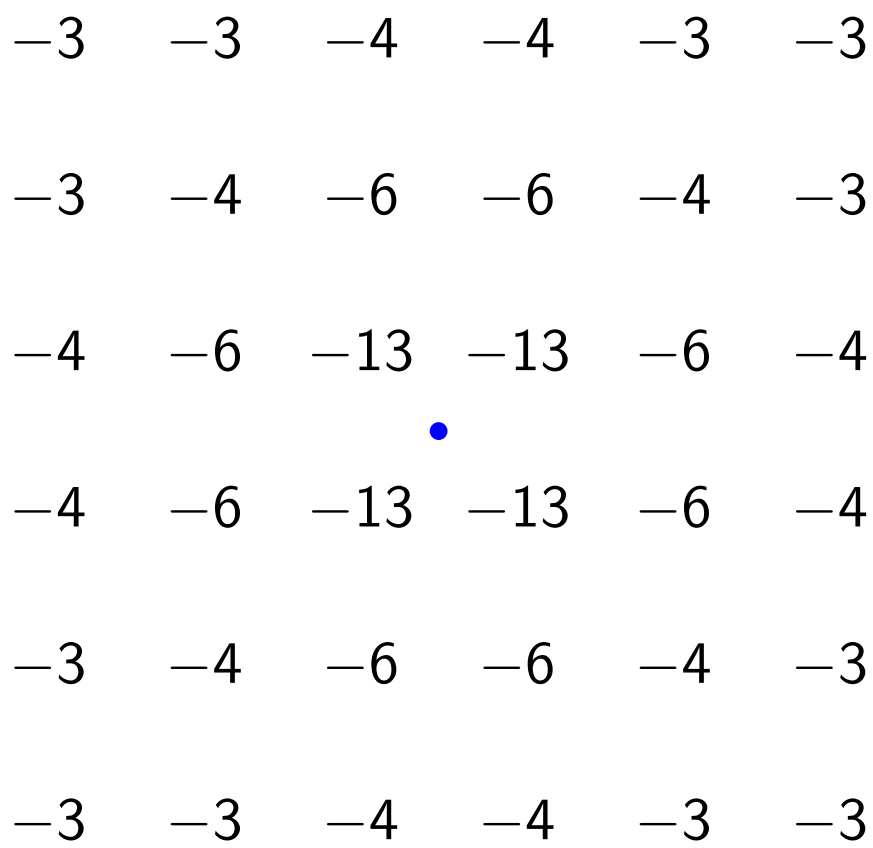
$V = k\frac{Q}{r}$

- Numbers are electric potential in Volts.

Another view of electric potential produced by a positively charged particle



Electric potential produced by a negatively charged particle



$Q < 0$

$V = k\frac{Q}{r}$

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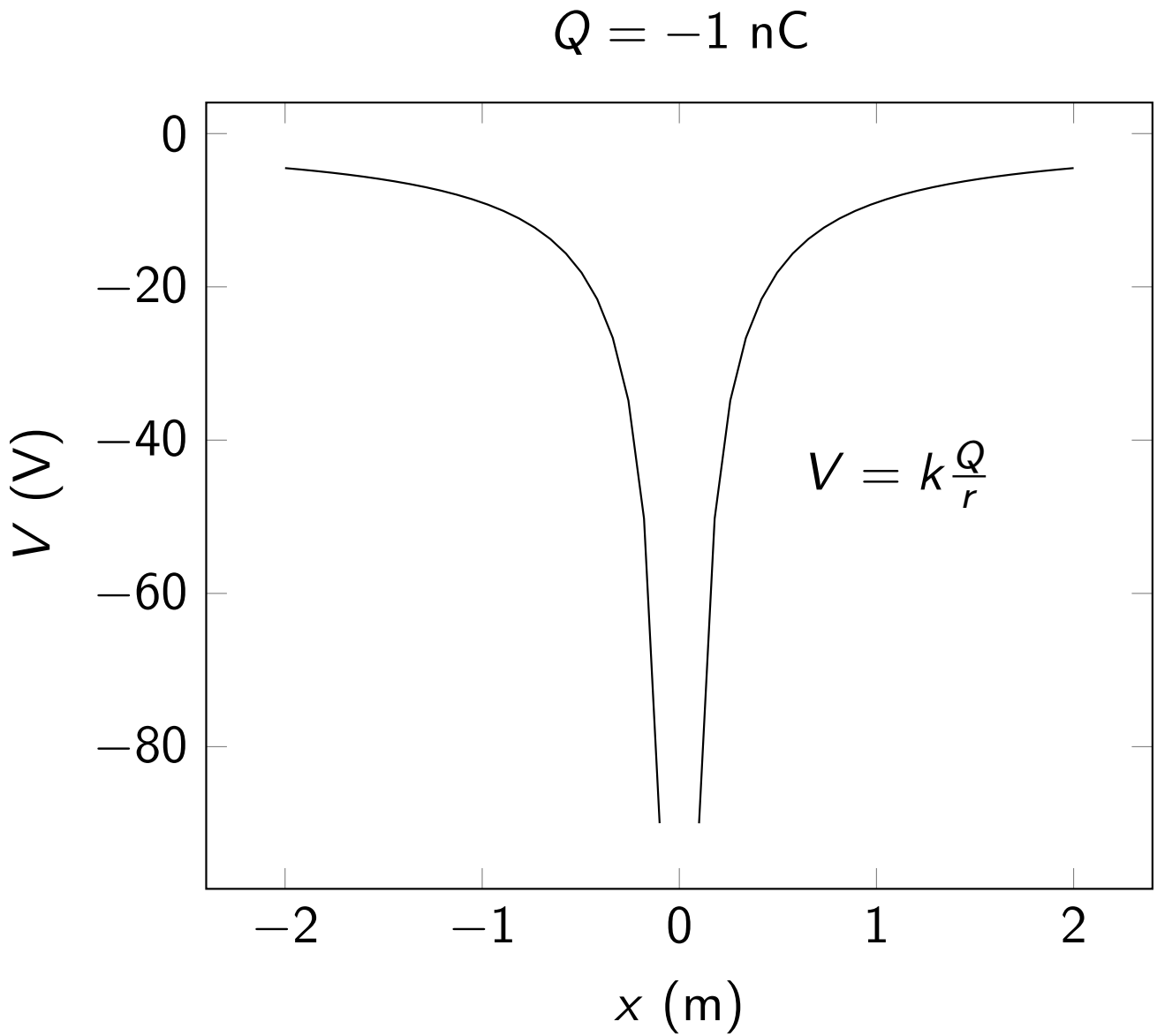
Another view of electric potential produced by a negatively charged particle

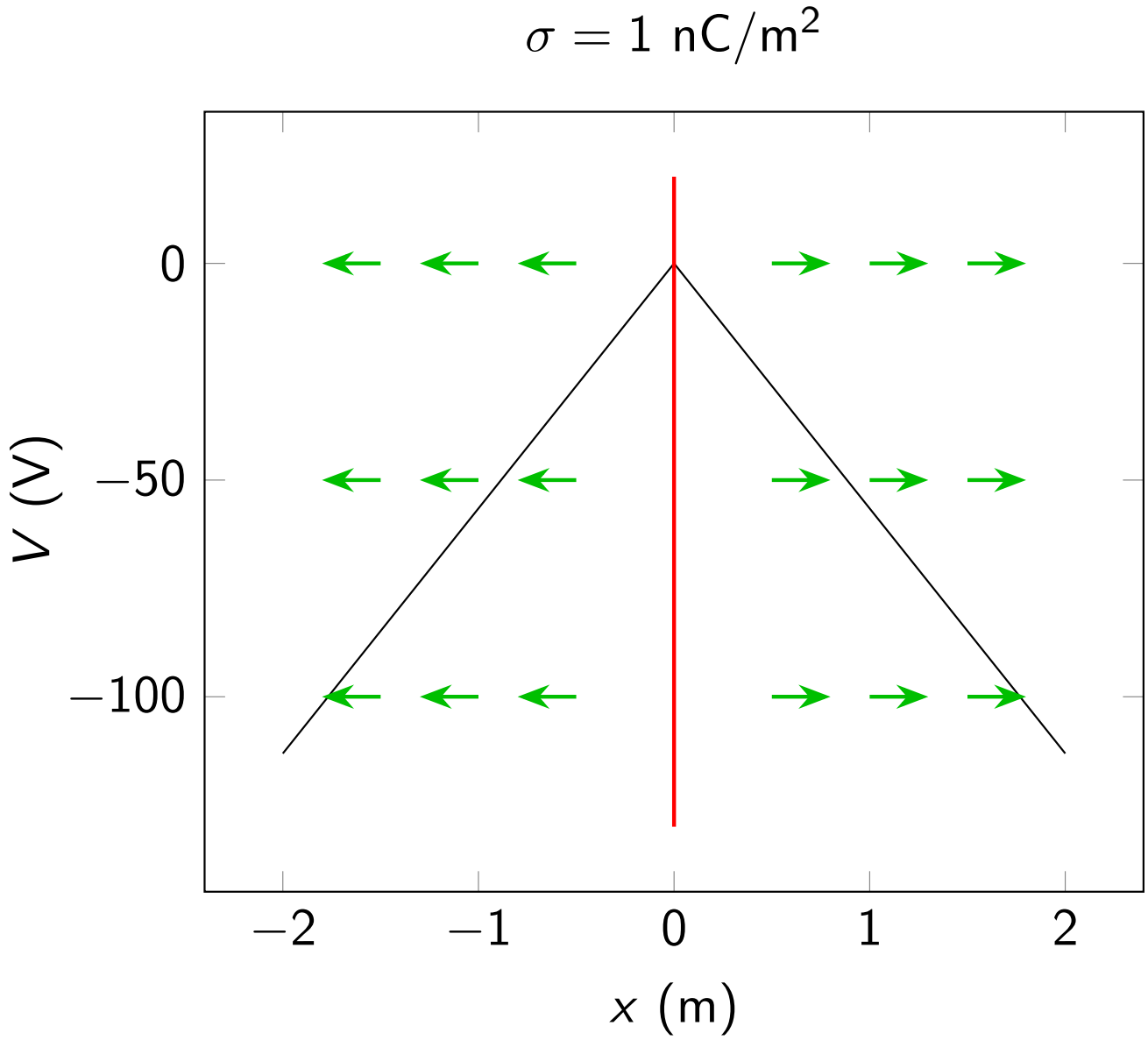


Electric potential produced by two particles

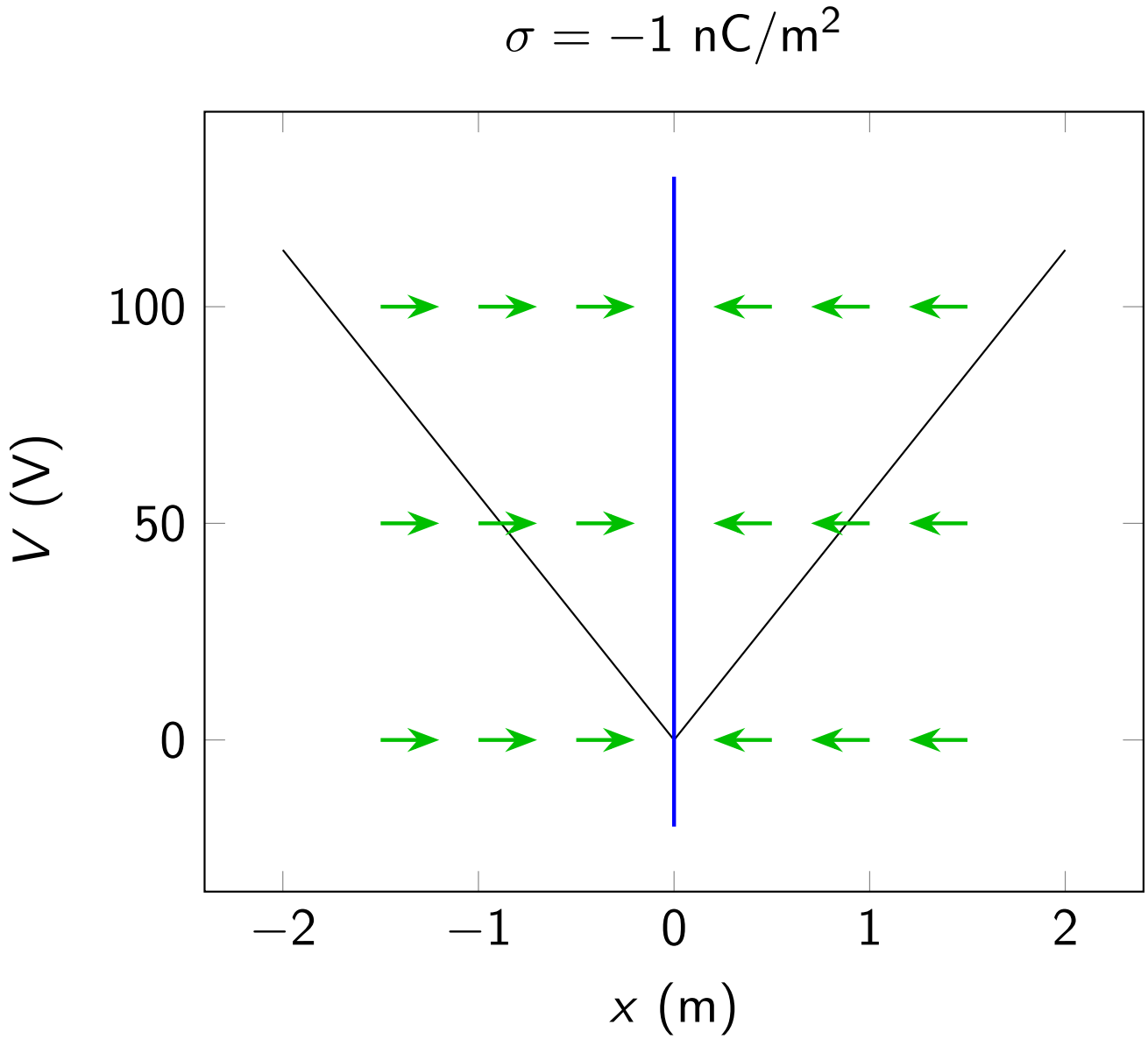
- To find the electric potential produced by two or more particles, add the electric potential produced by each particle alone.
- Good news: Electric potential is a scalar, so you only need to add numbers, not vectors.

$$V = k\frac{Q_1}{r_1} + k\frac{Q_2}{r_2}$$

Electric potential produced by a positively charged plate



Electric potential produced by a negatively charged plate



Electric potential produced by a charged plate

The electric potential produced by a plate with surface charge density σ at a distance x from the plate is

$$V = -2\pi k\sigma \left|x\right| .$$

Electric potential produced by two plates

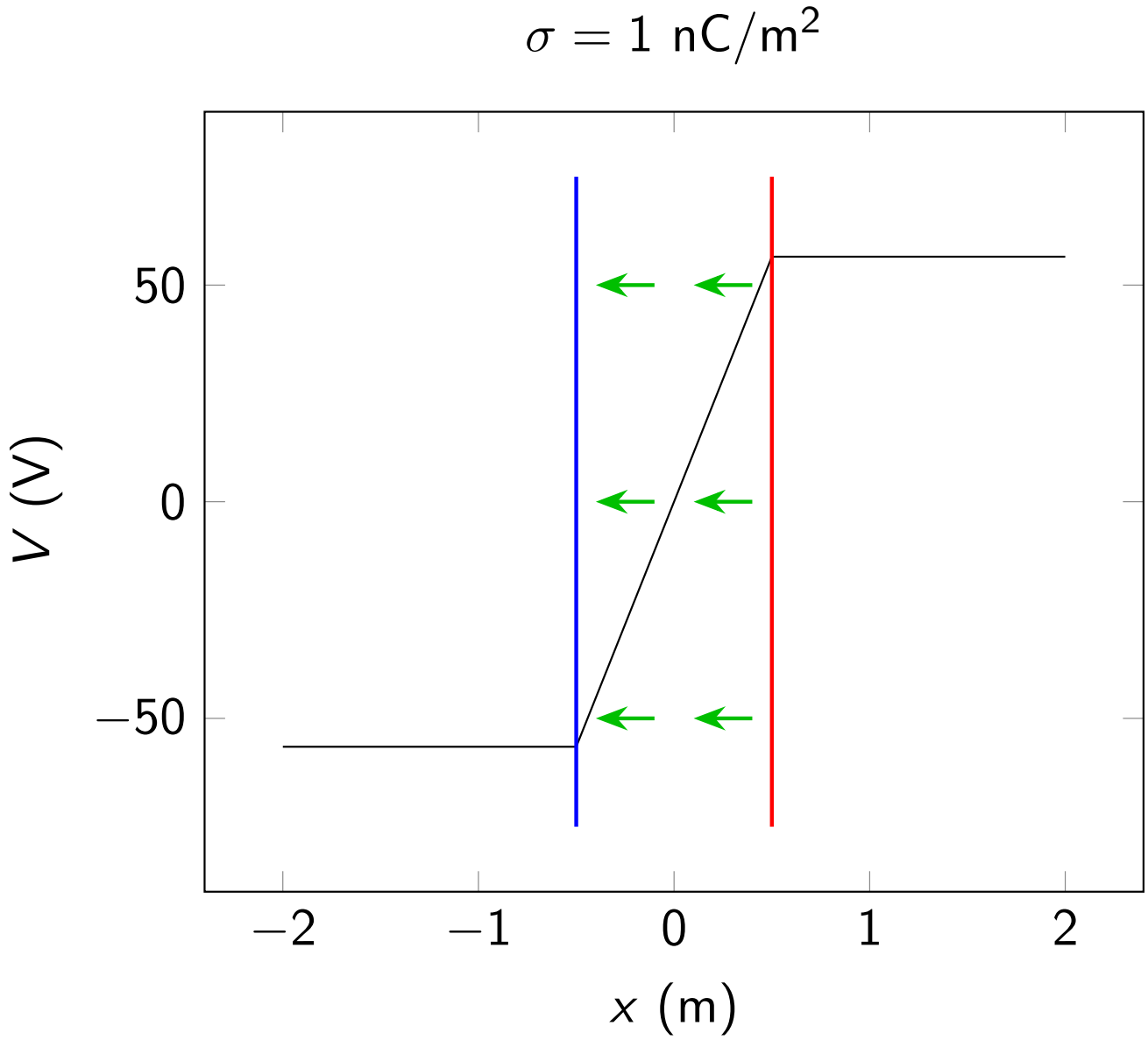
- To find the electric potential produced by two or more plates, add the electric potential produced by each plate alone.
- Electric potential is a scalar, so you only need to add numbers, not vectors.

$$V = -2\pi k\sigma_1 |x_1| - 2\pi k\sigma_2 |x_2|$$

Superposition Principle for Electric Potential

- The electric potential produced by multiple objects is the (scalar) sum of the electric potentials produced by each object alone.
- Uses for superposition:
  - Electric potential produced by two plates
  - Electric potential produced by a particle and a plate
  - Electric potential produced by two particles

Electric potential produced by a capacitor



Electric potential energy in the new electromagnetic theory

- Aspect 2: Electric potential invests charge with potential energy.

$$\mathrm{PE} = qV$$

Whose potential energy is it anyway?

- In Coulomb's old 18th century theory, the system of charged particles owns the potential energy.
- In Faraday and Maxwell's new 19th century theory, the electric field owns the potential energy.