Electric Potential Energy

Work and Energy for Charges

Electric Flux and Potential

I. Electric Flux
  - flux defined
  - Gauss's Law

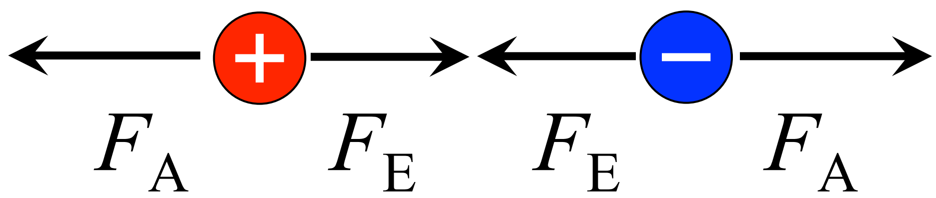
II. Electric Potential
  - work and energy of charge
  - potential defined
  - potential of discrete charge(s)
  - potential of charge distributions
  - field related to potential

III. Conductors

	The student will be able to:	HW:
1	Define and apply the concept of electric flux and solve related problems. ✓	1 – 5
2	State and apply Gauss's Law and solve related problems using Gaussian surfaces. ✓	6 – 17
3	Calculate work and potential energy for discrete charges and solve related problems including work to assemble or disassemble.	18 – 25
4	Define and apply the concept of electric potential and solve related problems for a discrete set of point charges and/or a continuous charge distribution.	26 – 32
5	Use the electric field to determine potential or potential difference and solve related problems.	33 – 36
6	Use potential to determine electric field and solve related problems.	37 – 39
7	State the properties of conductors in electrostatic equilibrium and solve related problems.	40 – 46

Work and Energy for Charges

Work must be done by an external force F_A in order to separate opposite charges attracted to one another by force F_E.



Work and Energy for Charges

Opposite charges that have been separated represent **potential energy** because of the attractive force F_E between such charges. (There is the potential for work to be done by the electric force F_E as the separation decreases and charges come together.)

Work and Energy for Charges

Likewise work must be done by an external force F_A in order to *decrease* the separation of *like* charges that repel one another F_E.

Work and Energy for Charges

Like charges that have been pushed together represent potential energy because of the *repulsive* force F_E. (There is the potential for work to be done by the electric force F_E as the separation *increases* and charges move apart.)

Electric Potential Energy

$$U = \frac{kq_1q_2}{r}$$

OR

$$U = \frac{q_1q_2}{4\pi\varepsilon_0 r}$$

where: U = electric potential energy
q = point charge (may be + or −)
r = separation of the two charges

Note: The calculated result is relative to a separation of infinity!

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Electric Potential

$$V = \frac{U}{q}$$

OR

$$V = -\frac{W}{q}$$

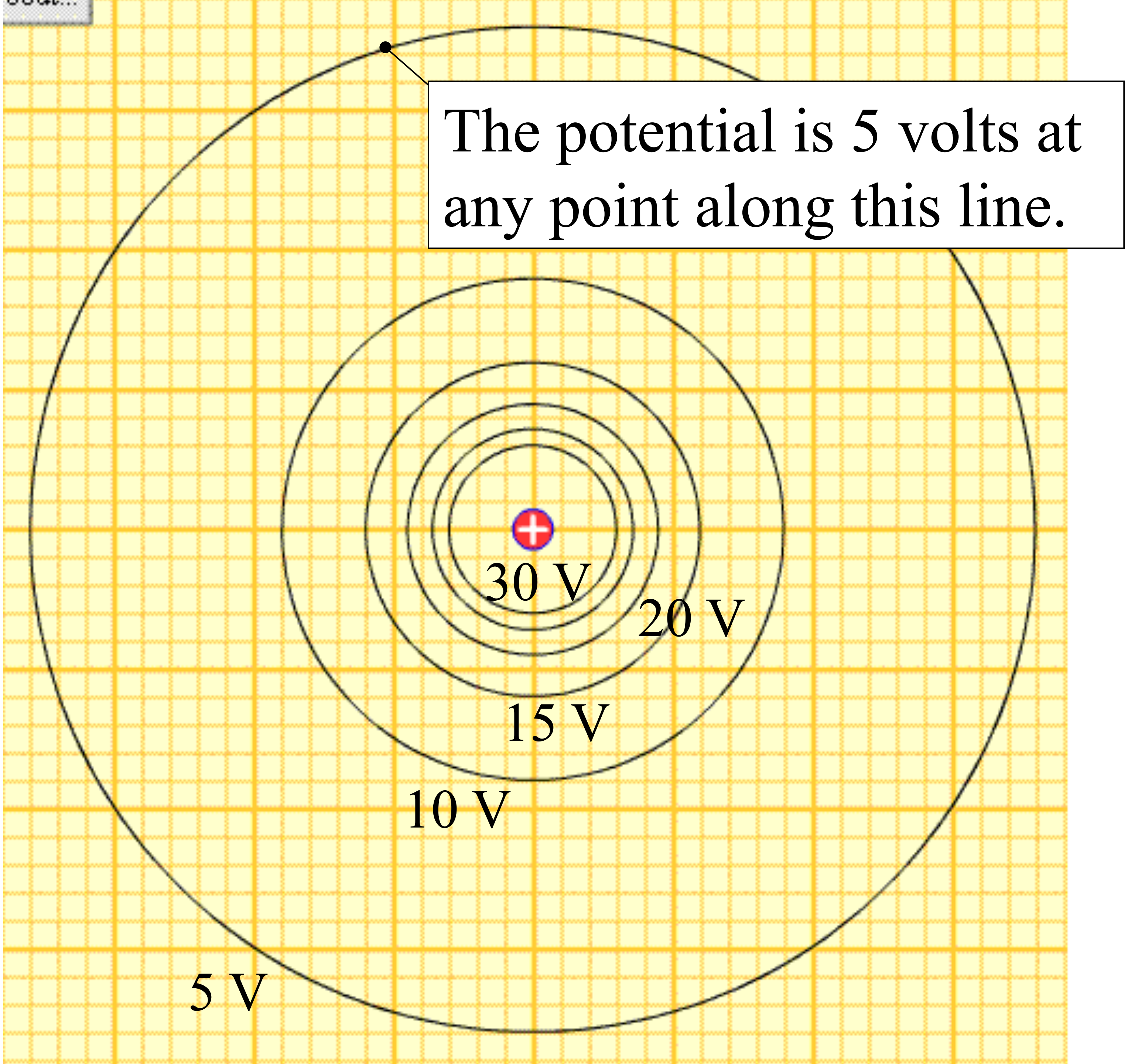
where: U = potential energy of q relative to infinity

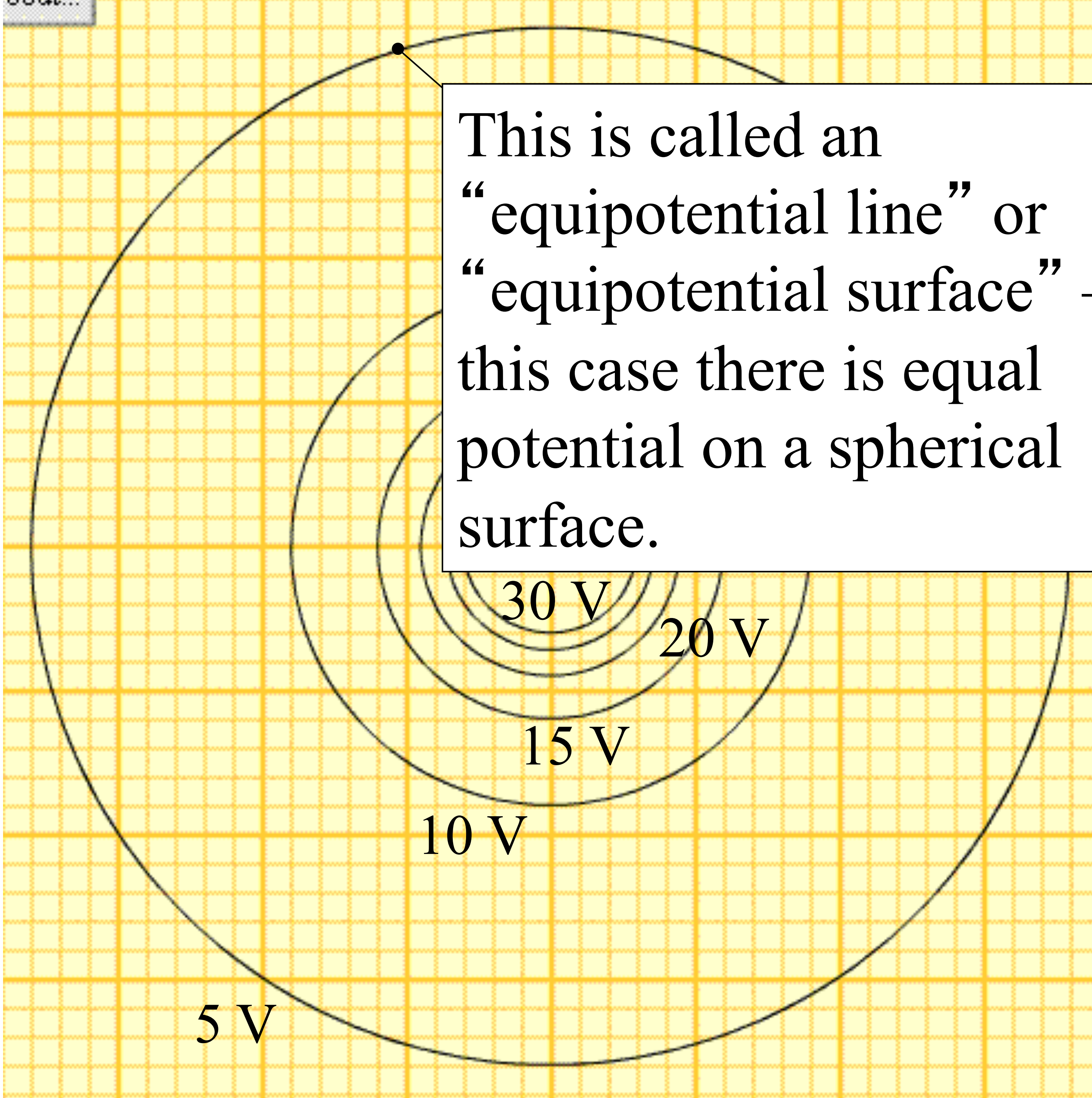
W = work done by electrostatic force on charge q from infinity to a particular position

Units of Electric Potential

- The SI unit for electric potential is the **volt**.
- One volt is equal to one joule of work or energy per every one coulomb of charge:

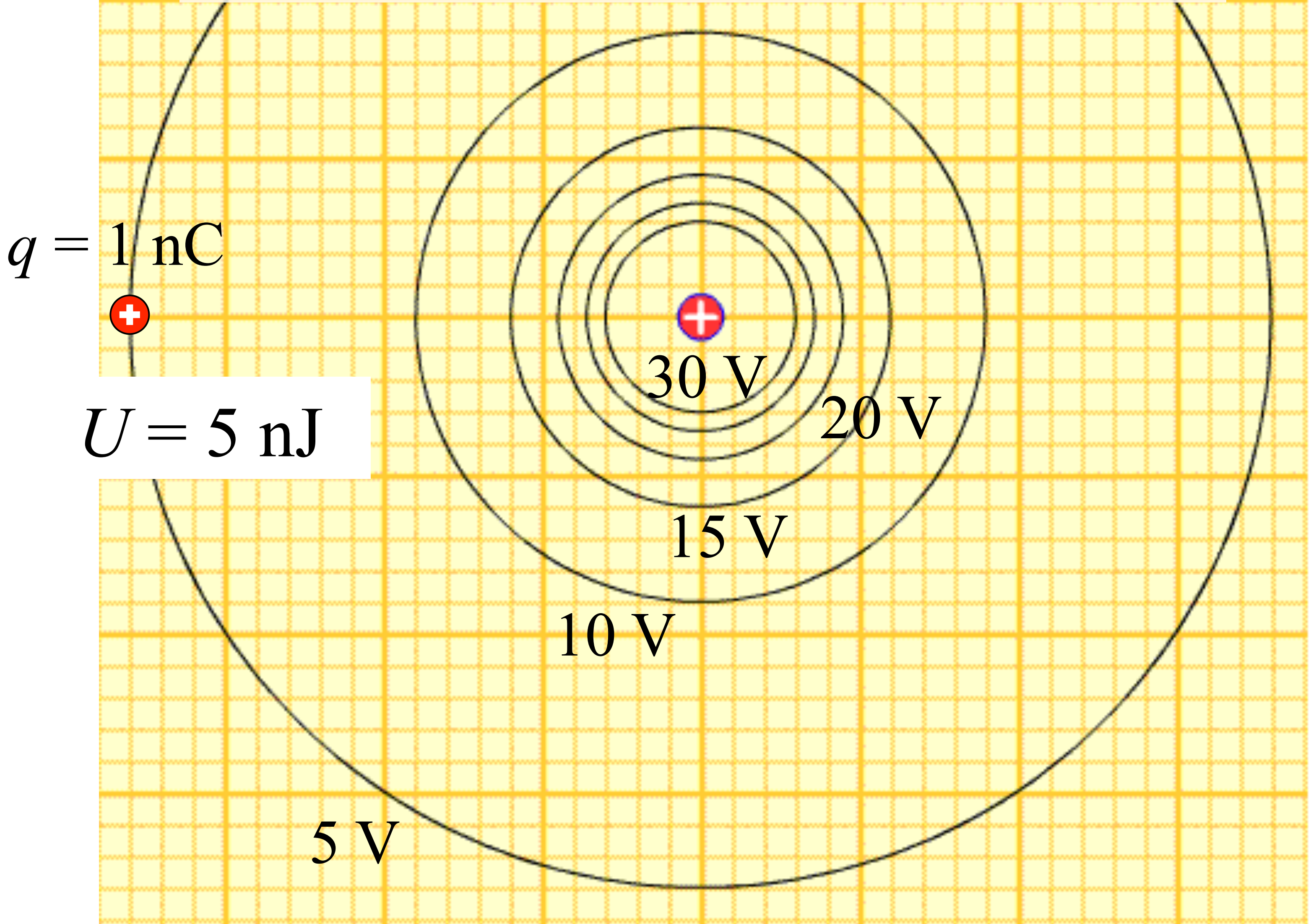
$$1\ \text{V} = 1\ \text{J/C}$$


The potential is 5 volts at any point along this line.
30 V
20 V
15 V
10 V
5 V



This is called an "equipotential line" or "equipotential surface" – in this case there is equal potential on a spherical surface.

The potential energy of a point charge located on an equipotential can be found by $U = qV$.



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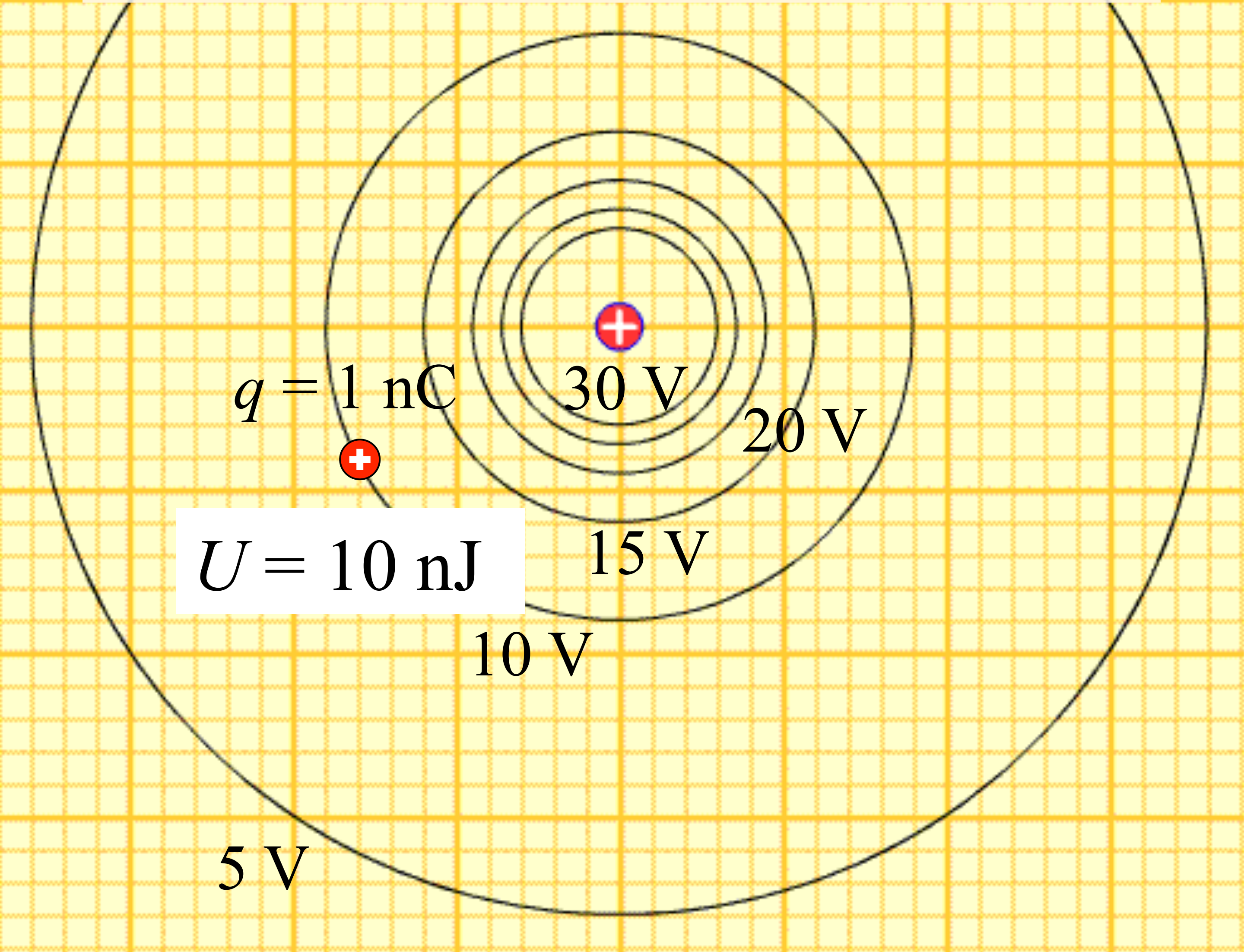

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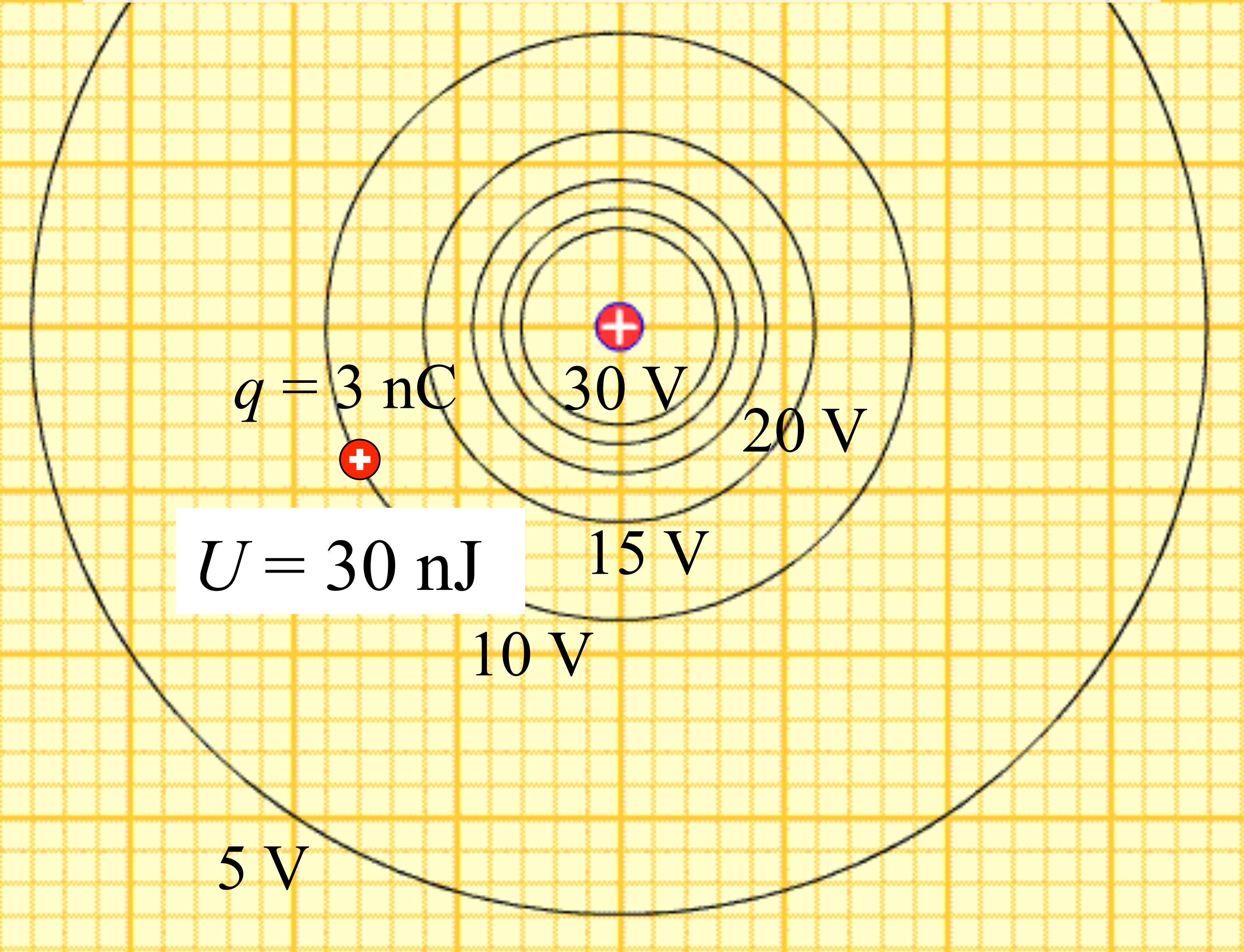

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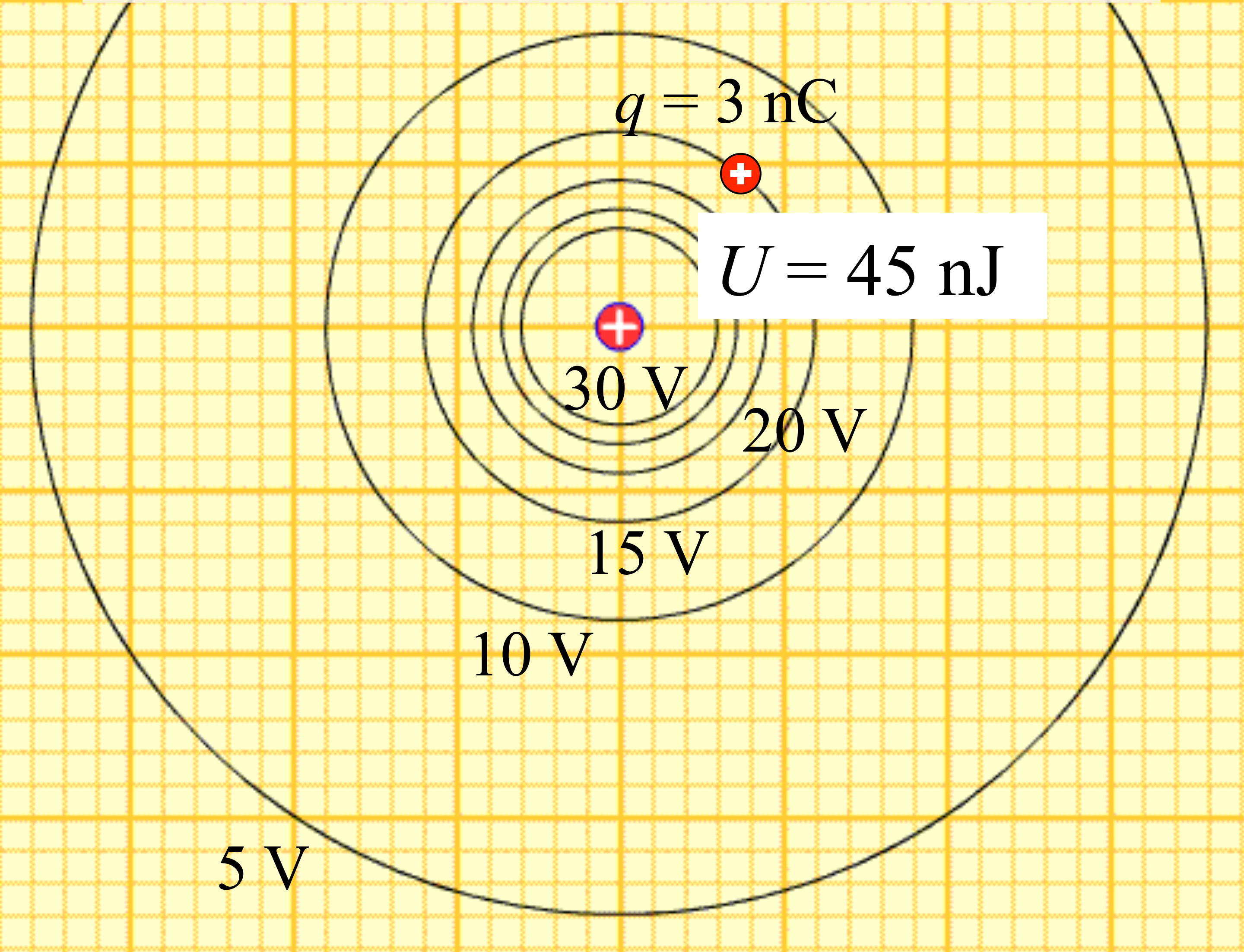

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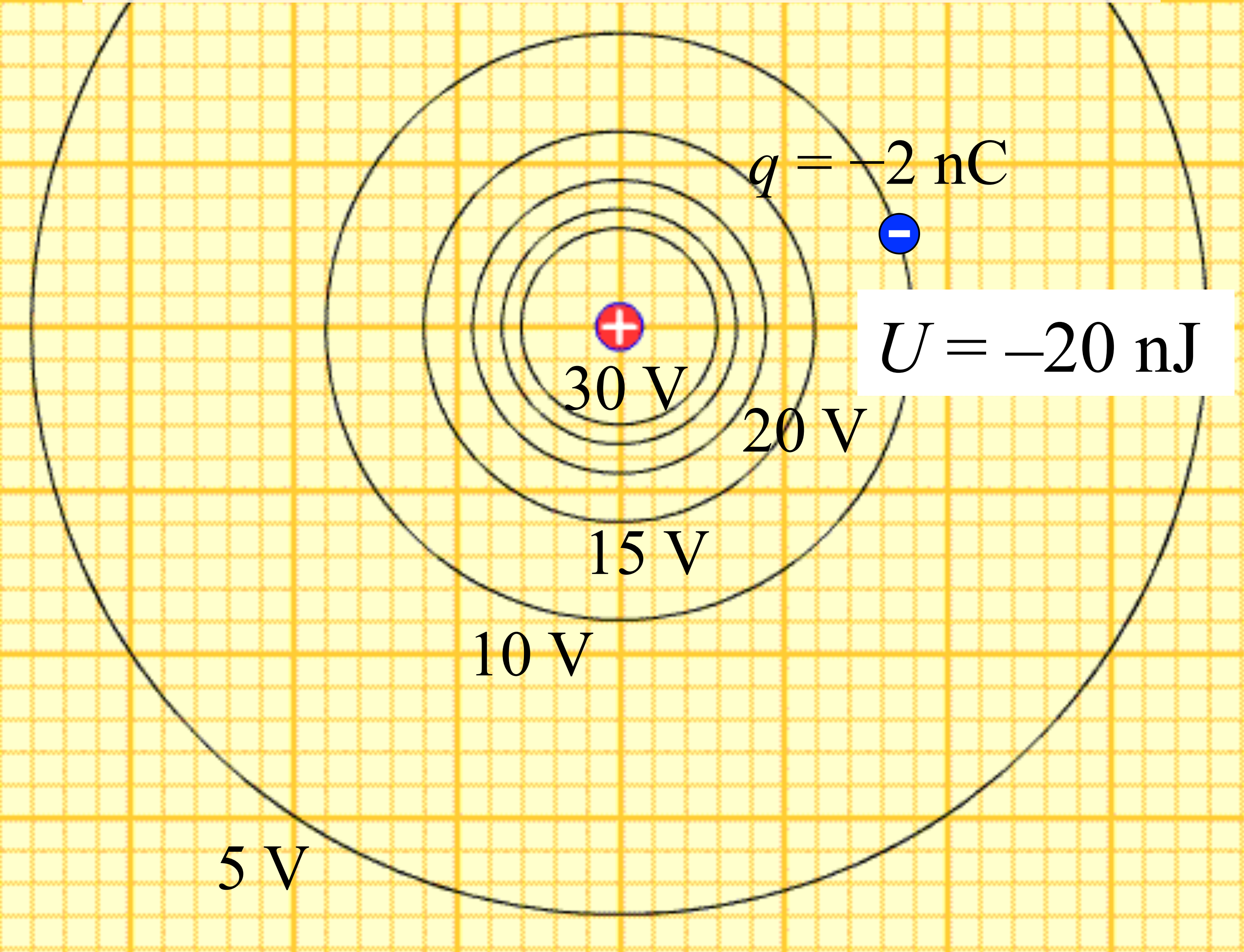

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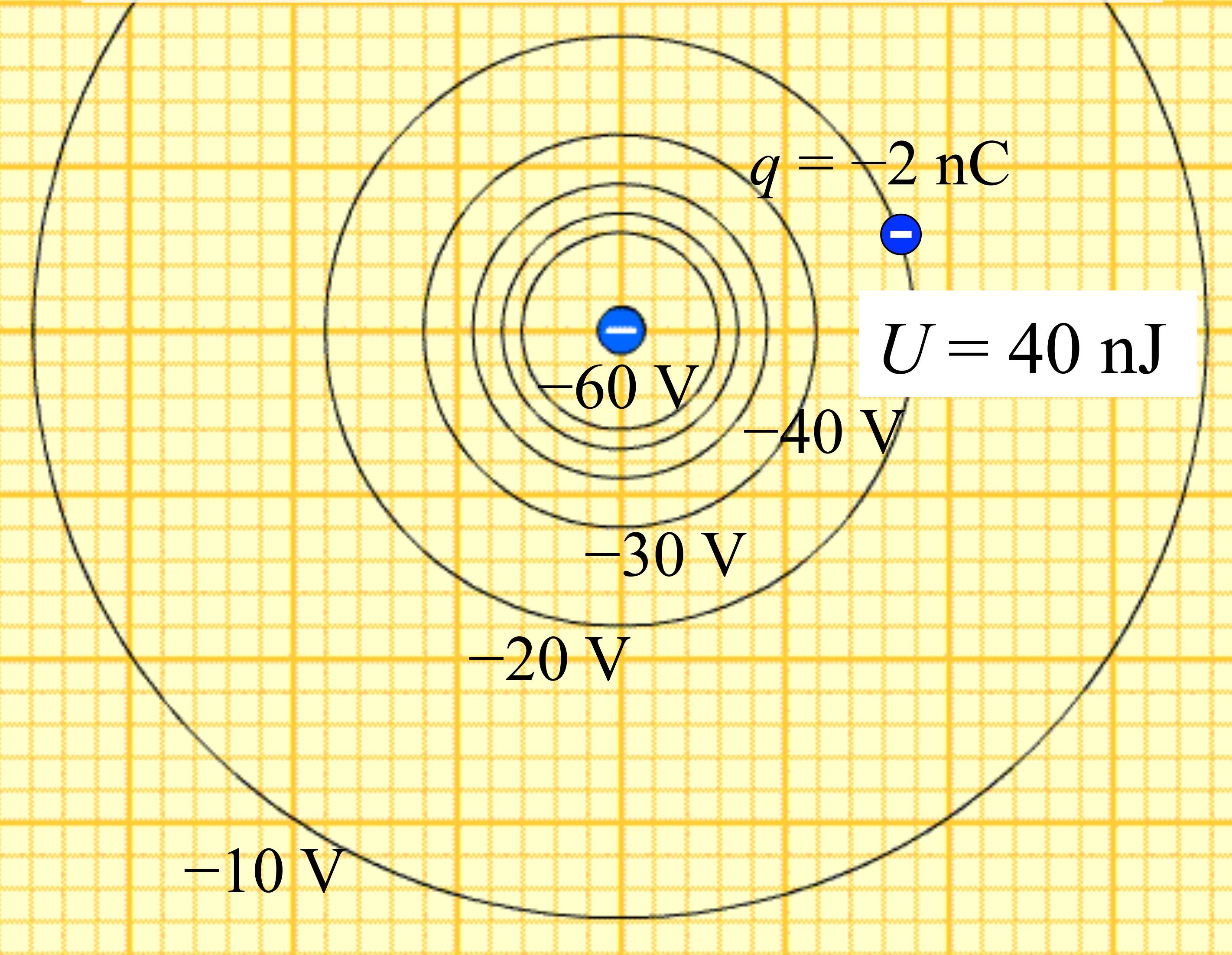


Potential Near a Point Charge

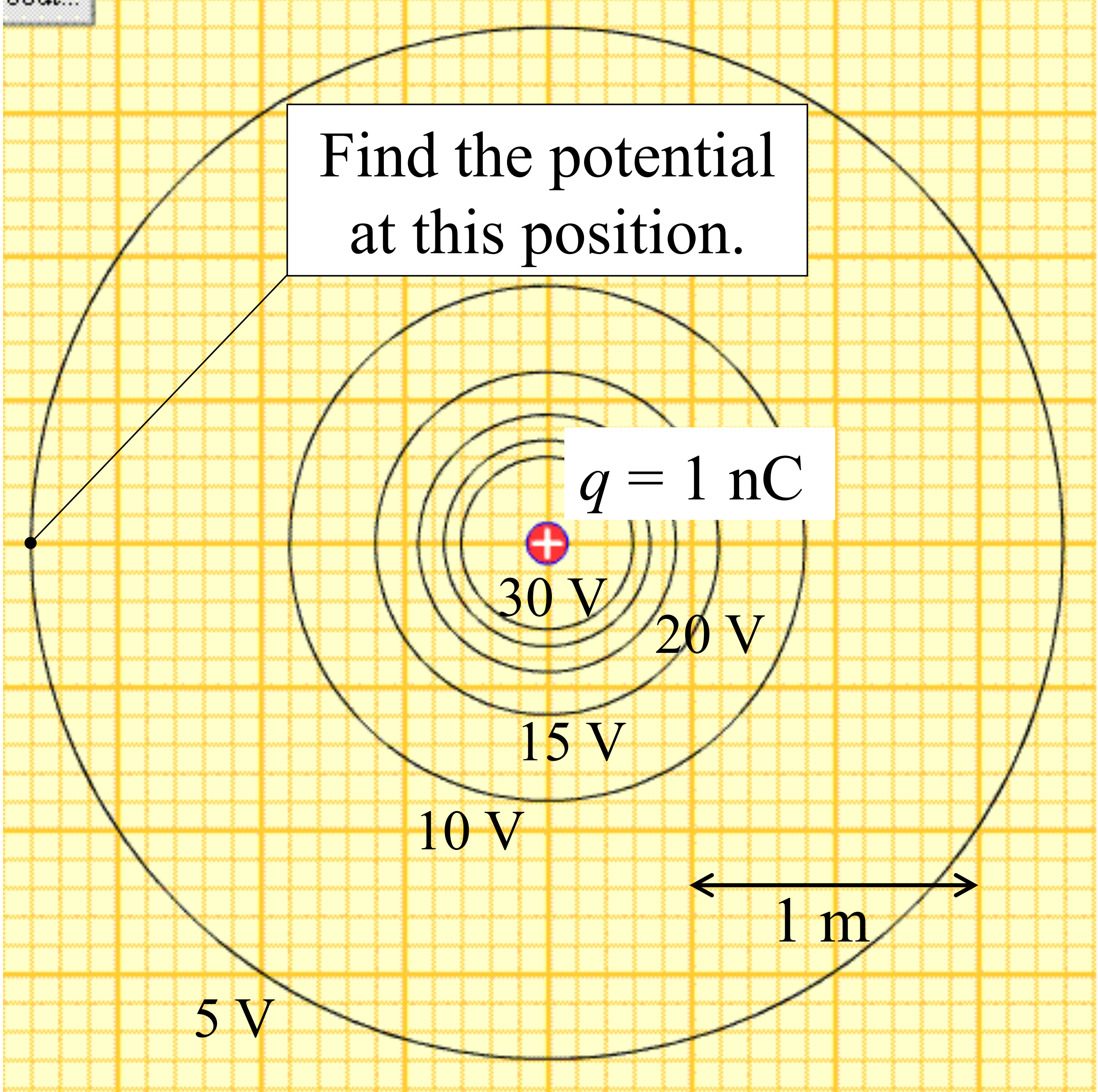
$$V = \frac{kq}{r}$$

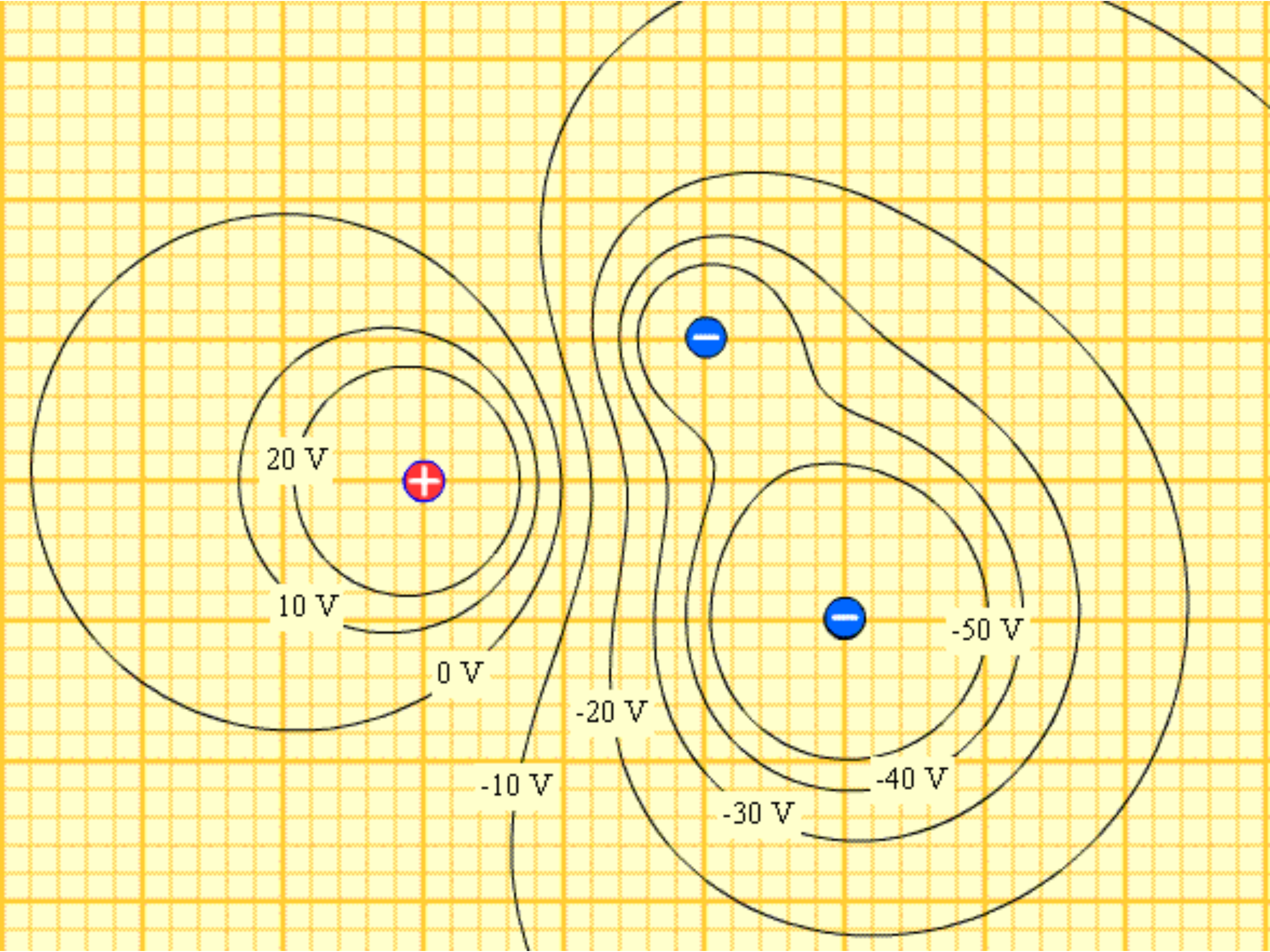
OR

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

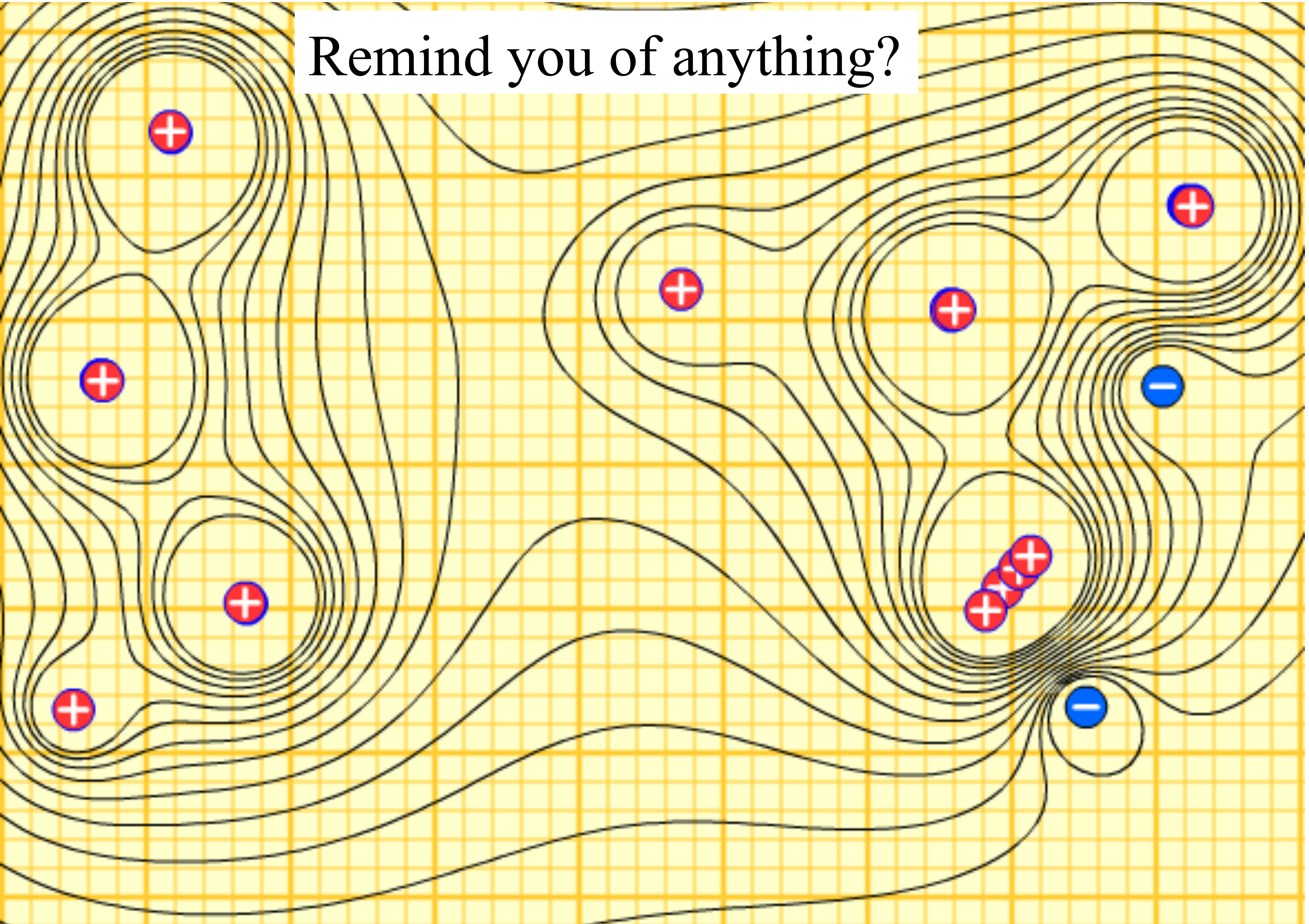
where: V = electric potential at position **r** (position *relative* to q)

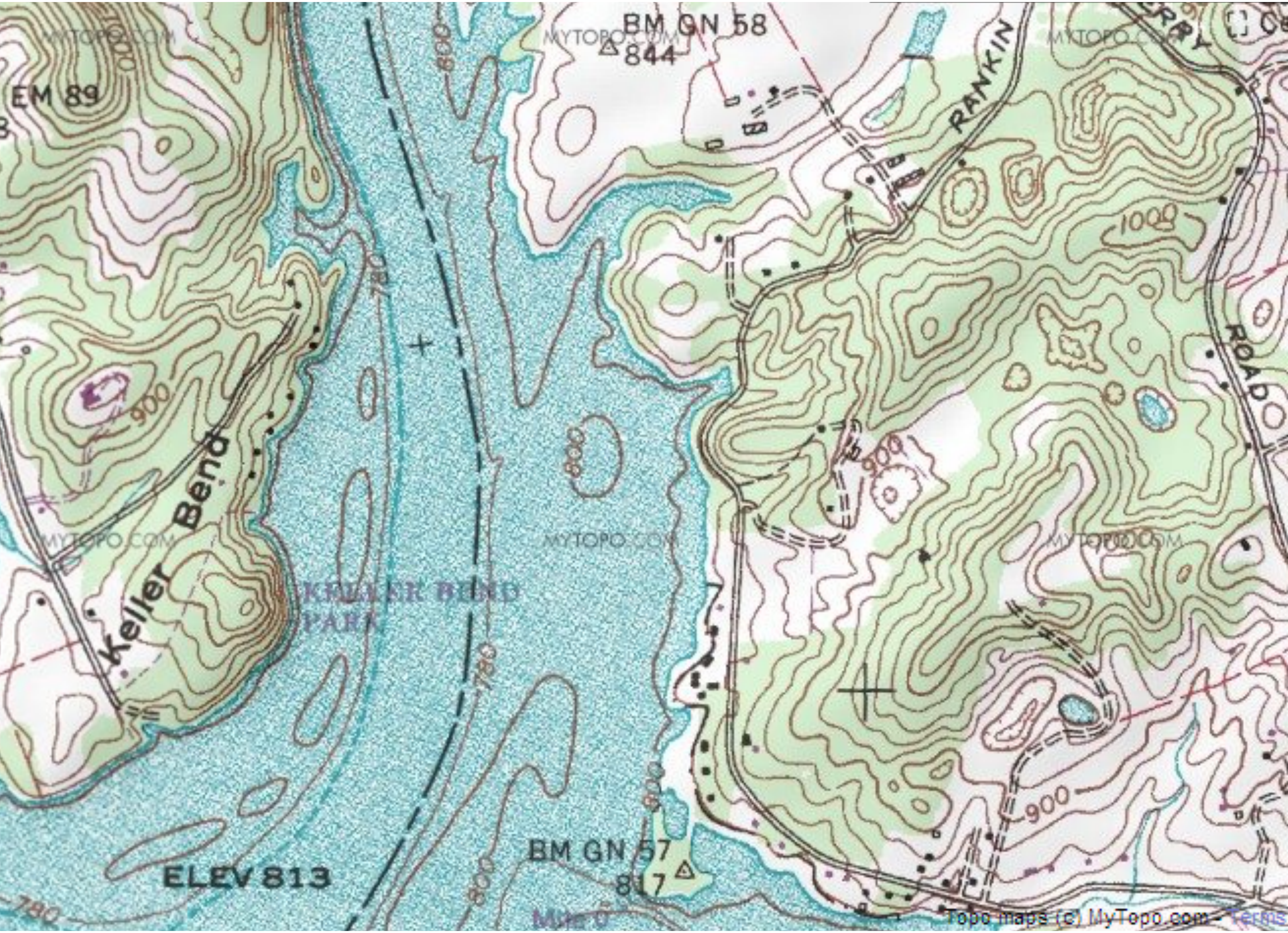
q = point charge (may be + or −)


Find the potential at this position.
q = 1 nC
30 V
20 V
15 V
10 V
5 V
1 m


20 V
10 V
0 V
-10 V
-20 V
-30 V
-40 V
-50 V

Remind you of anything?




BM GN 58
844
EM 89
RANKIN
1000
780
900
Keller Bend
KELLER BEND PARK
ROAD
900
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BM GN 57
817
ELEV 813
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Mile 0
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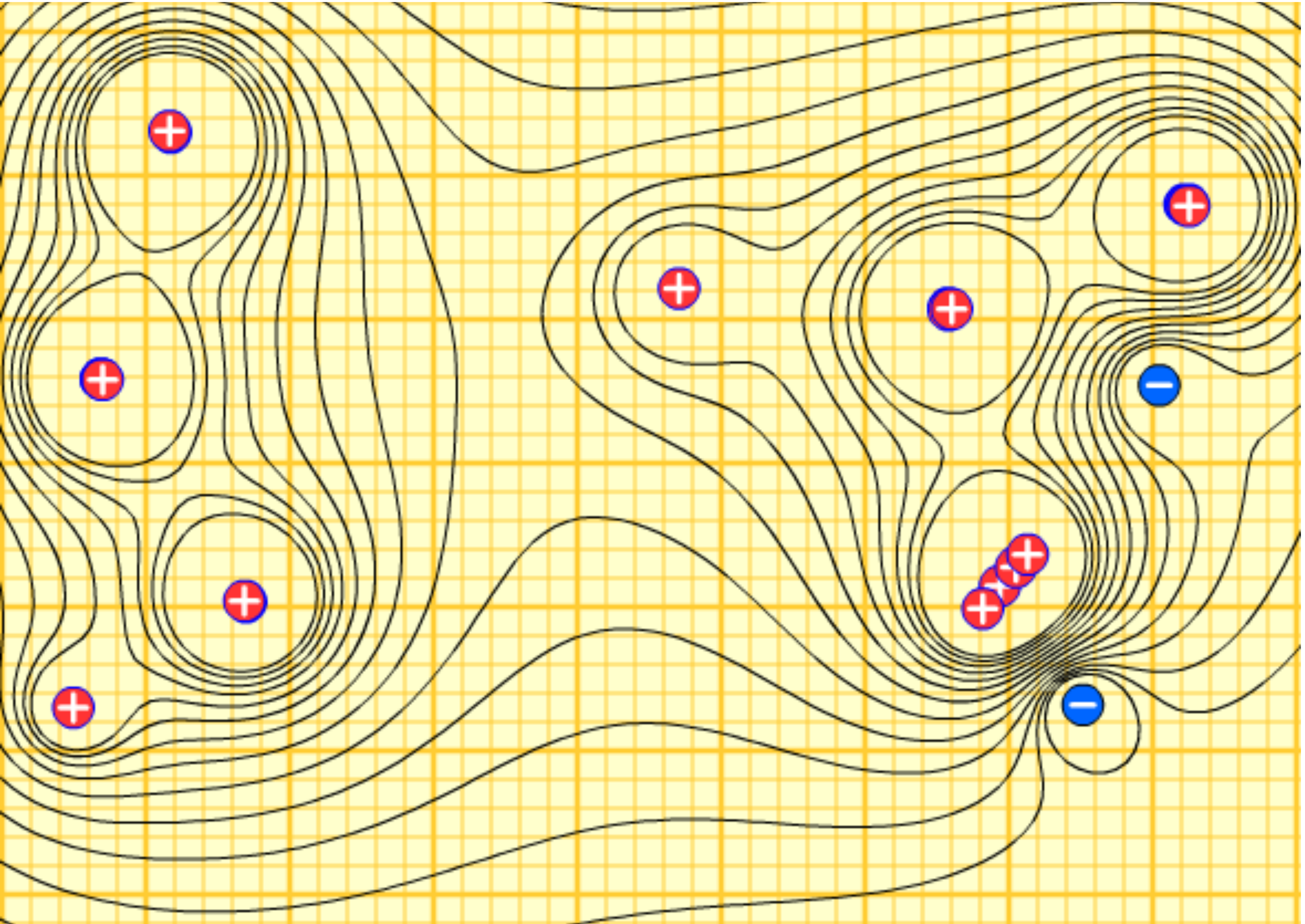
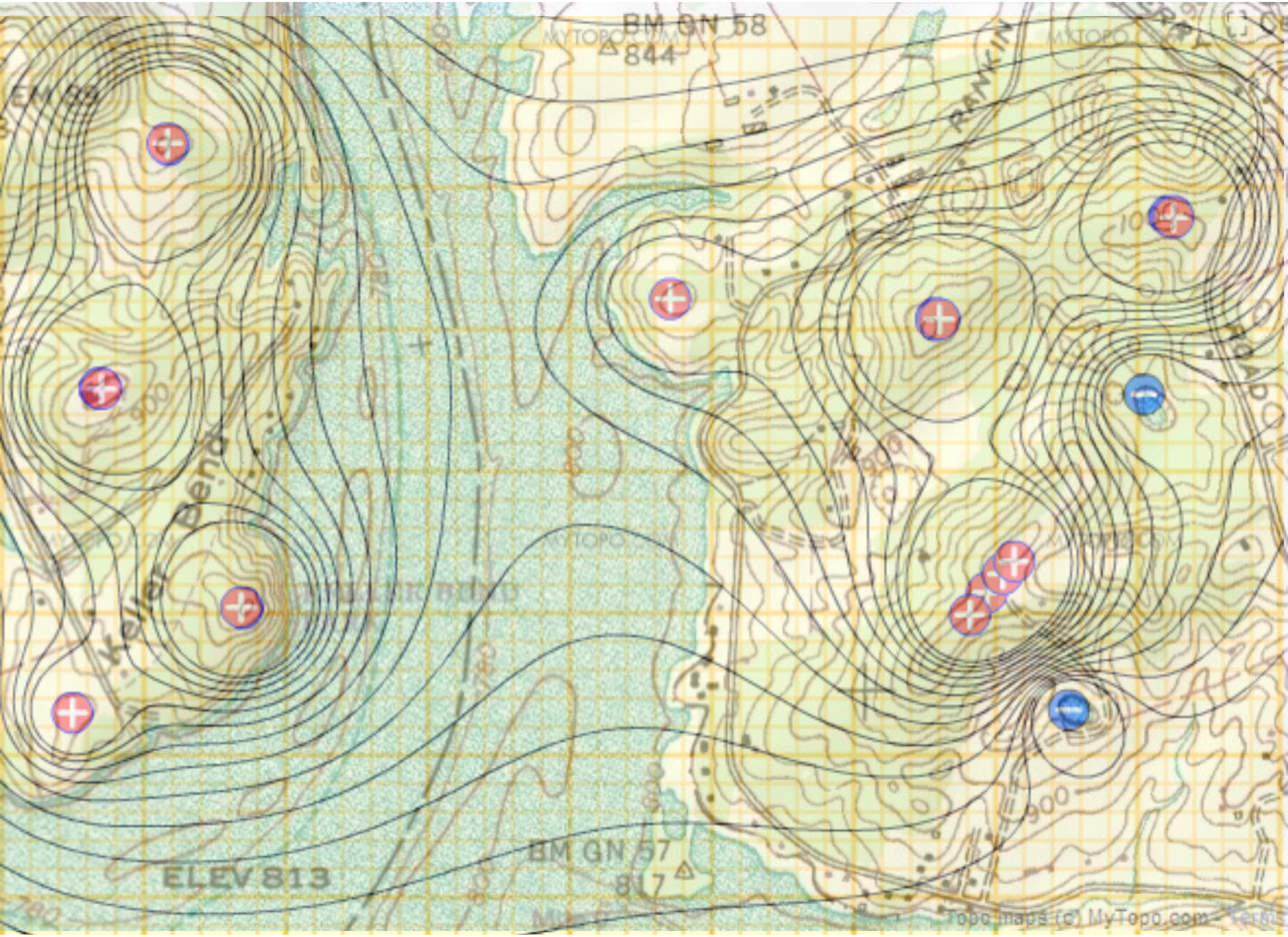
Topo maps (c) MyTopo.com - Terms




BM GN 58
844
MYTOPO.COM
RANKIN
Keller Bend
900
BM GN 57
817
ELEV 813
Topo maps (c) MyTopo.com

Potential Near Multiple Point Charges

$$V = \sum_i \frac{kq_i}{r_i}$$

OR

$$V = \sum_i \frac{q_i}{4\pi\varepsilon_0 r_i}$$

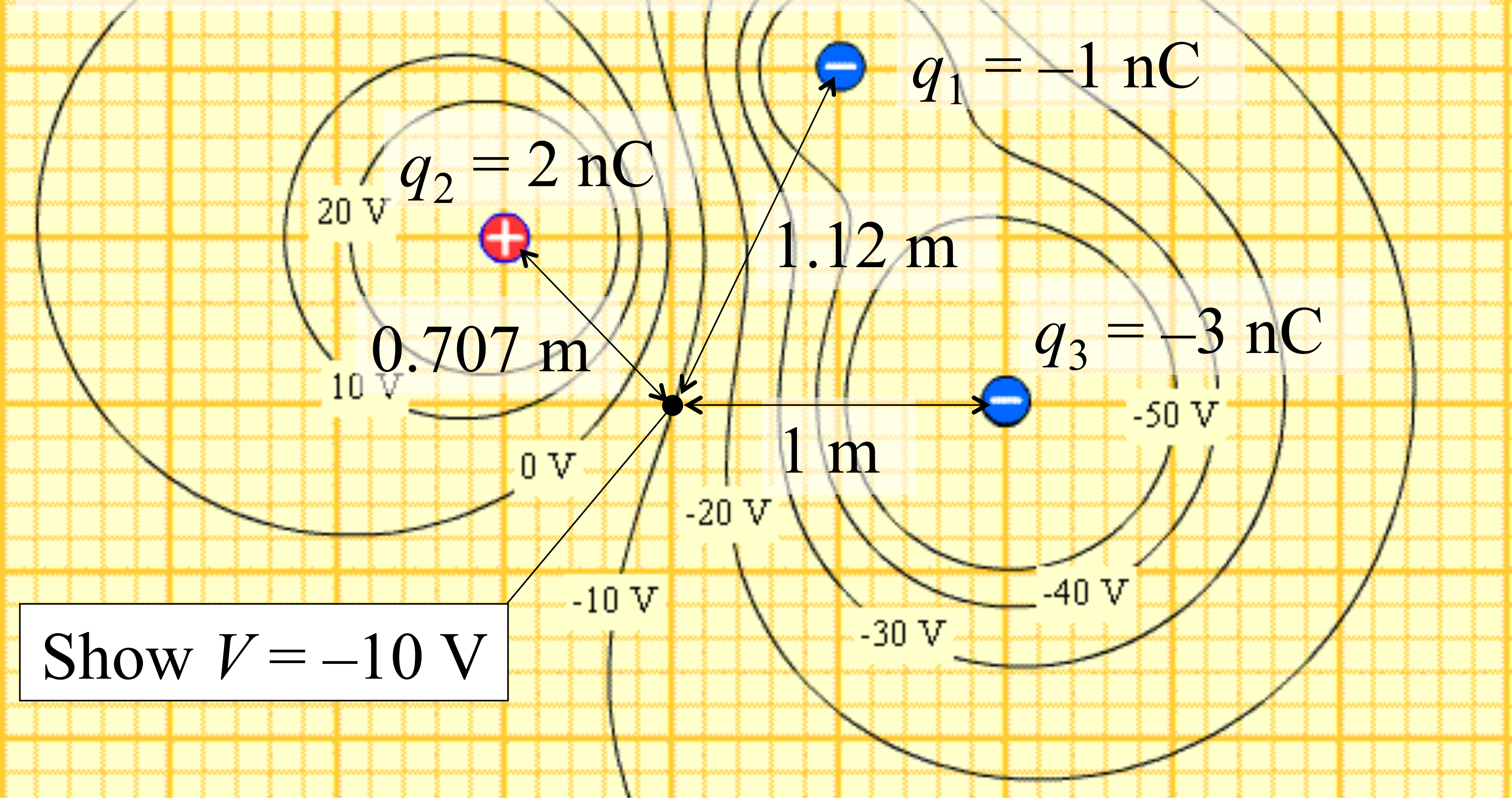
note: The values of r extend from each q to the particular point at which V is found.

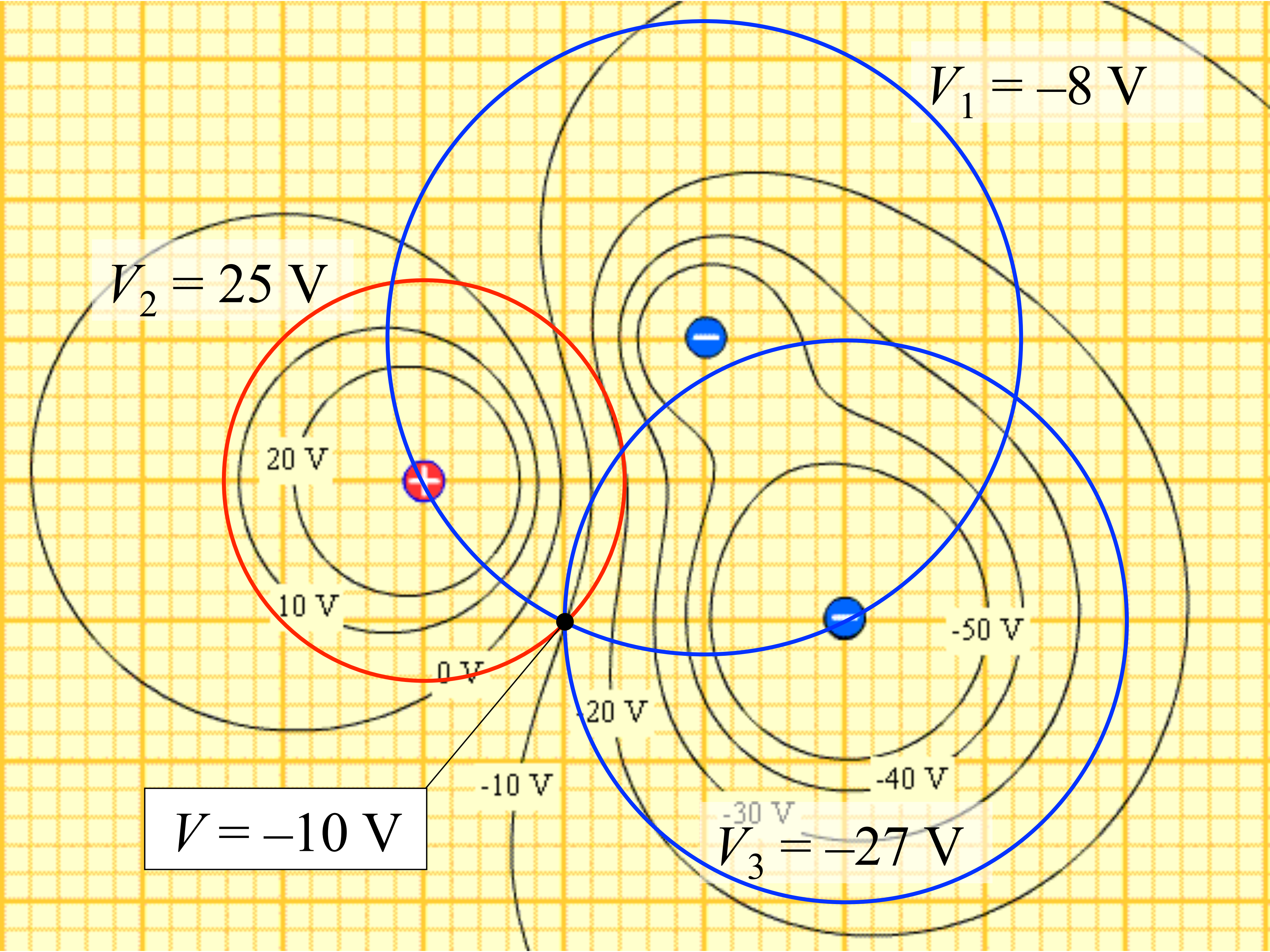
$$V = V_1 + V_2 + V_3$$

$$V = k(\text{-1 nC})/1.12 + k(\text{2 nC})/0.707 + k(\text{-3 nC})/1$$

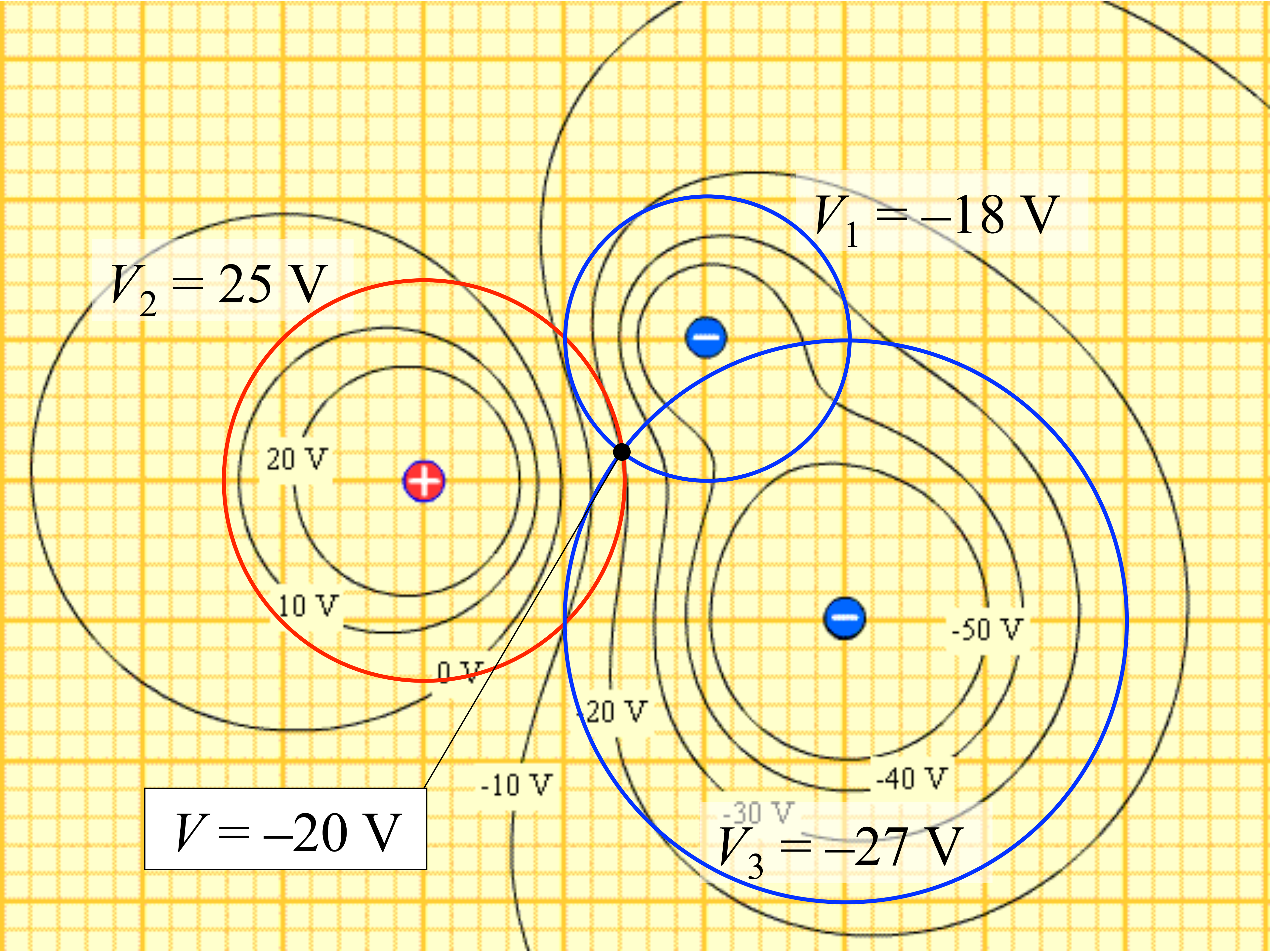
$$V = (-8) + 25 + (-27)$$

$$V = -10 \text{ V}$$

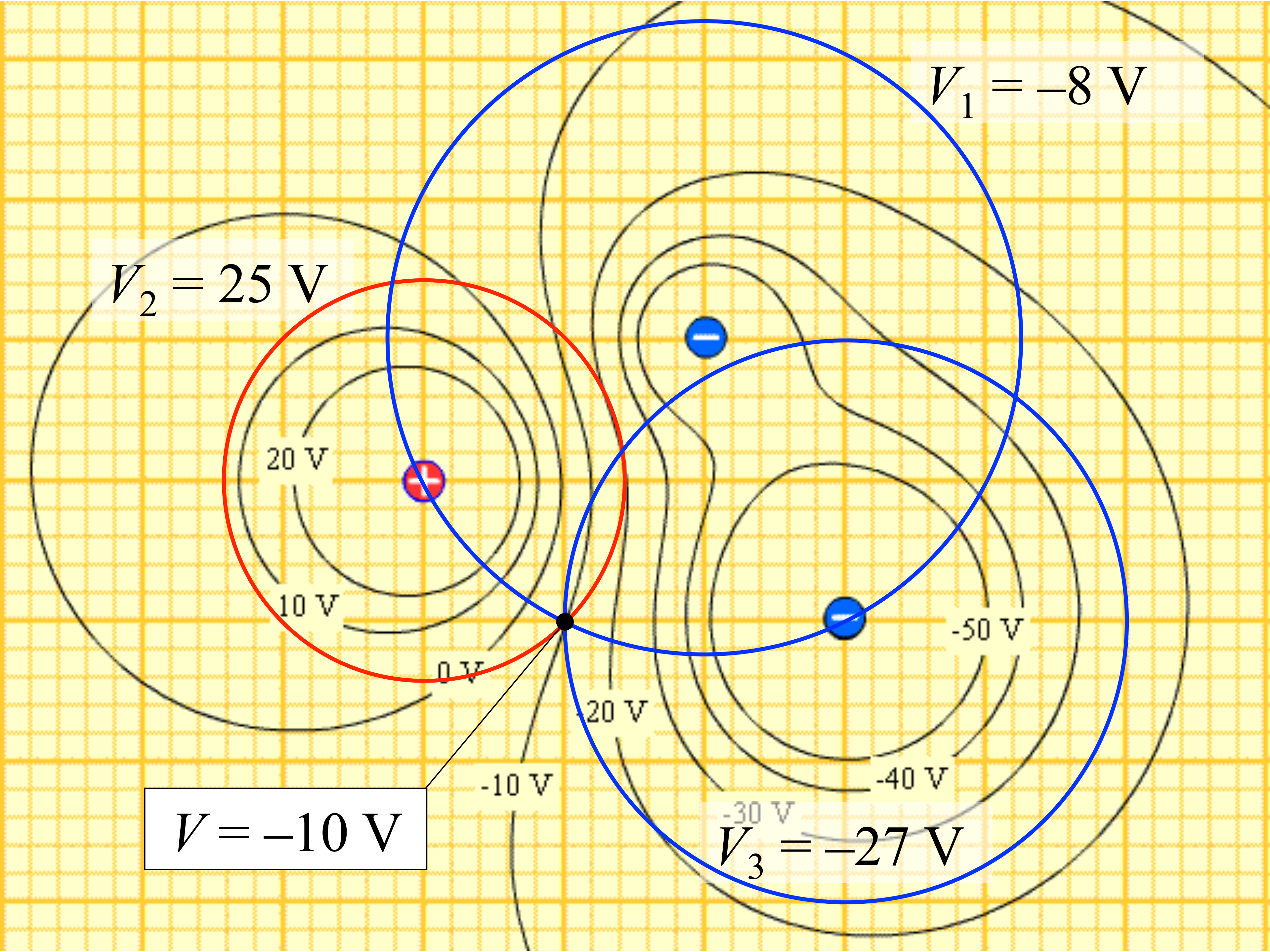




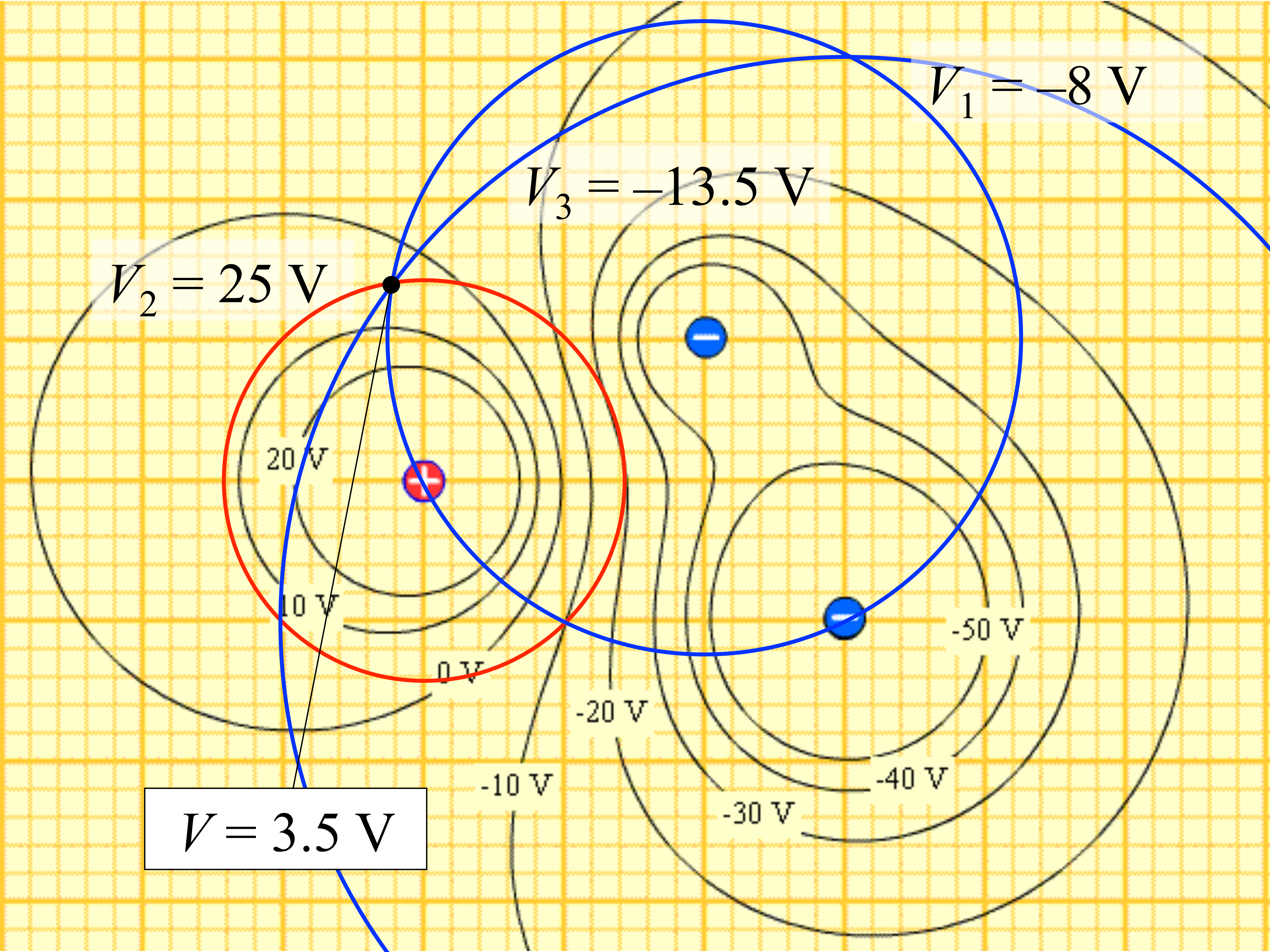
$V_1 = -8$ V
$V_2 = 25$ V
$V_3 = -27$ V
$V = -10$ V
20 V
10 V
0 V
-10 V
-20 V
-30 V
-40 V
-50 V



$V_1 = -18$ V
$V_2 = 25$ V
$V_3 = -27$ V
$V = -20$ V
20 V
10 V
0 V
-10 V
-20 V
-30 V
-40 V
-50 V



V1 = –8 V
V2 = 25 V
20 V
10 V
0 V
–10 V
–20 V
–30 V
–40 V
–50 V
V = –10 V
V3 = –27 V



$V_1 = -8$ V
$V_3 = -13.5$ V
$V_2 = 25$ V
20 V
10 V
0 V
-10 V
-20 V
-30 V
-40 V
-50 V
$V = 3.5$ V

Potential Near a Continuous Charge Distribution

$$V = \int \frac{kdq}{r}$$

OR

$$V = \int \frac{dq}{4\pi\varepsilon_0 r}$$

Typically *dq* is rewritten in terms of:
charge per length (λ),
charge per area (σ),
or charge per volume (ρ).