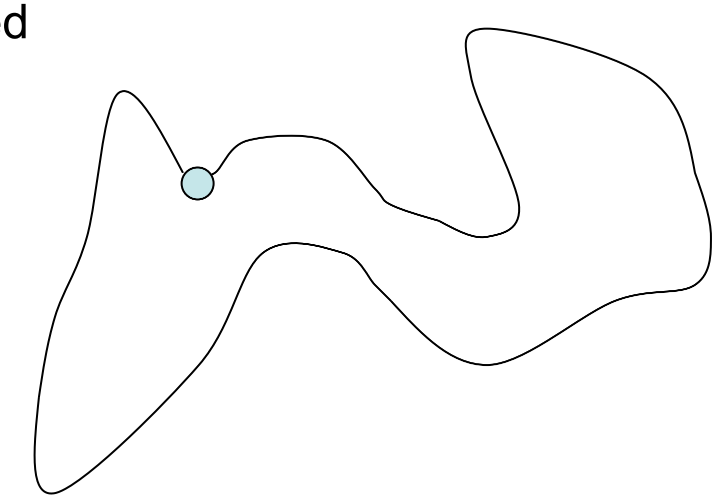
24.1-24.3

#11: Potential

Potential energy can be defined for a ***conservative force***



If you move from point A and come back to point A, then work done = 0

Gravity

$F = mg$ Constant acceleration

$U_h = mgh$

$U_g = 0$

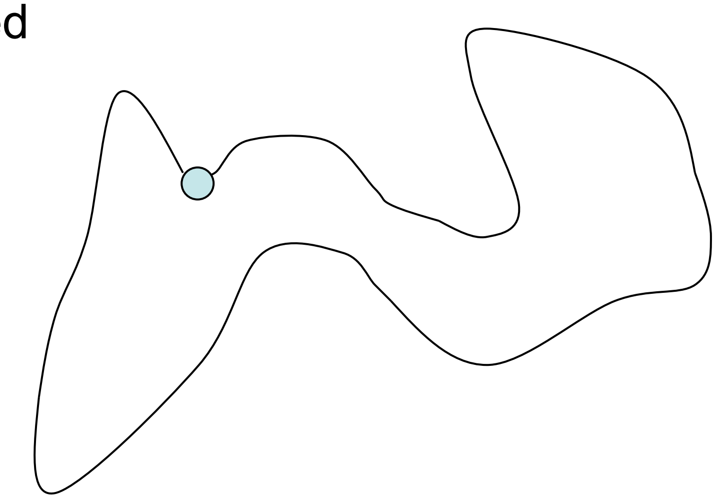
Work done $W = U_{init} - U_{final} = -\Delta U$

Potential energy is only a function of the position

24.1-24.3

#11: Potential

Potential energy can be defined for a ***conservative force***



$$W = U_{init} - U_{final} = -\Delta U$$

A particularly useful quantity is the work (and/or U) ***per unit charge***

We call this the electric potential, or often just ***potential, V***

$$V = \frac{U}{q_0} \qquad U = q_0 V$$

$$\vec{E} = \frac{\vec{F}_q}{q} \qquad \vec{F} = q\vec{E}$$

If you move from point A and come back to point A, then work done = 0

$$W = qV_{init} - qV_{final}$$

$$W = -q\Delta V$$

Somewhat analogous to Force and Electric Field

A. Volta
(1745-1827)

Potential and potential energy are not the same

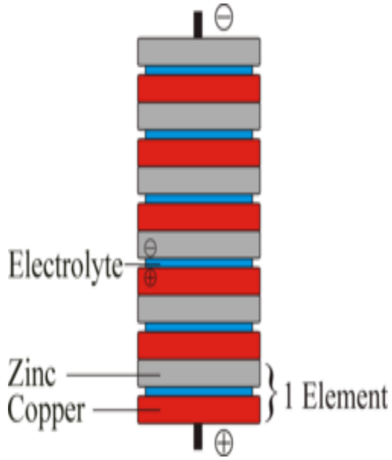
Potential V

Scalar field defined everywhere
SI Unit of is J/C = Volt (V)

Potential Energy U

Of an object or objects
SI Unit of Joules (J)

1800 Voltaic pile = 1st battery



A battery uses chemical reactions to create a potential difference between two points (terminals).

Connecting a conductor between the terminals allows charge to move from higher to lower potential. The change in potential energy of the charges is converted into thermal energy (heat/light).

The work that is done is proportional to the amount of charge that moves between the potential difference.

$$W = -q\Delta V$$

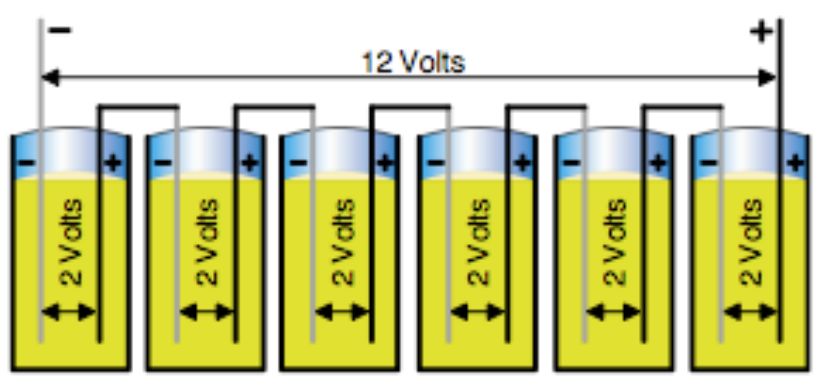
Why do I need 6 batteries?

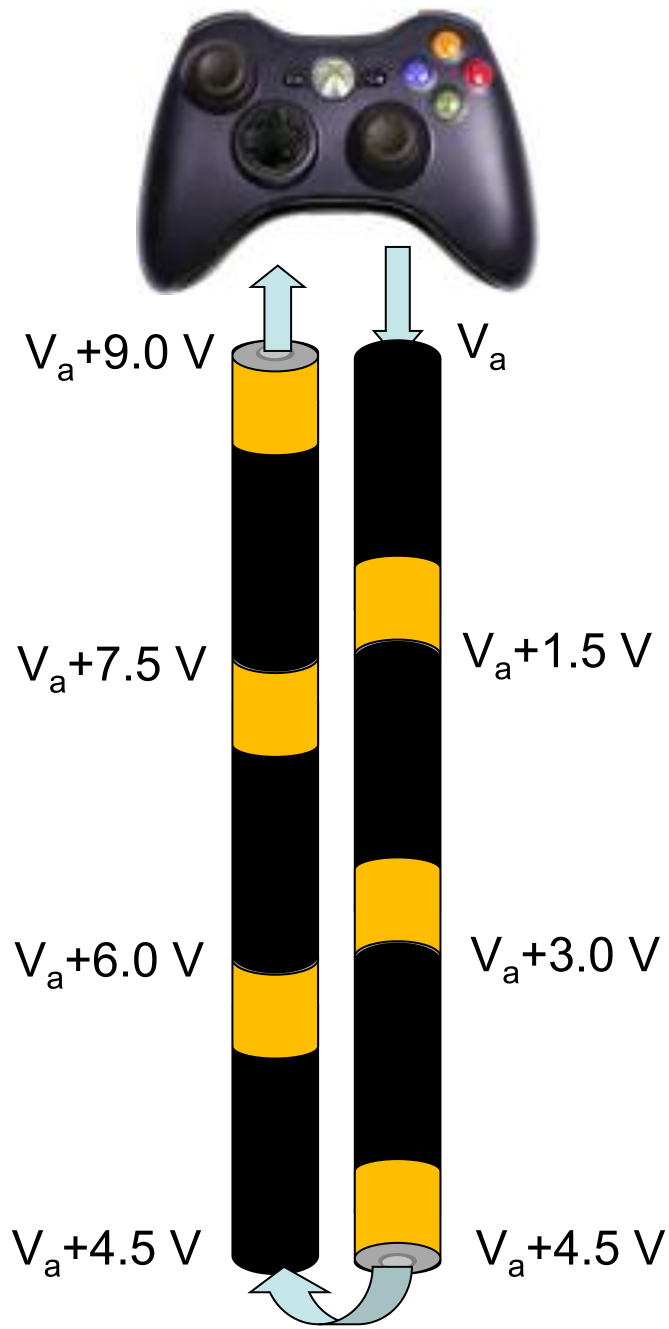
Electromotive force (emf) is a function of the chemical properties of the battery.

Adding batteries in series allows for a range of emf (potential differences) to be achieved using the same type of battery.

Higher input potential differences are advantageous for some electrical circuits.

A car battery uses 6 cells within a single battery to create a potential difference of 12 V.





We move a proton from point i to point f in a uniform electric field. Is positive or negative work done by (a) the electric field and (b) our force? (c) Does the electric potential energy increase or decrease? (d) Does the proton move to a point of higher or lower electric potential?

Equipotential surface

V is a constant at all points

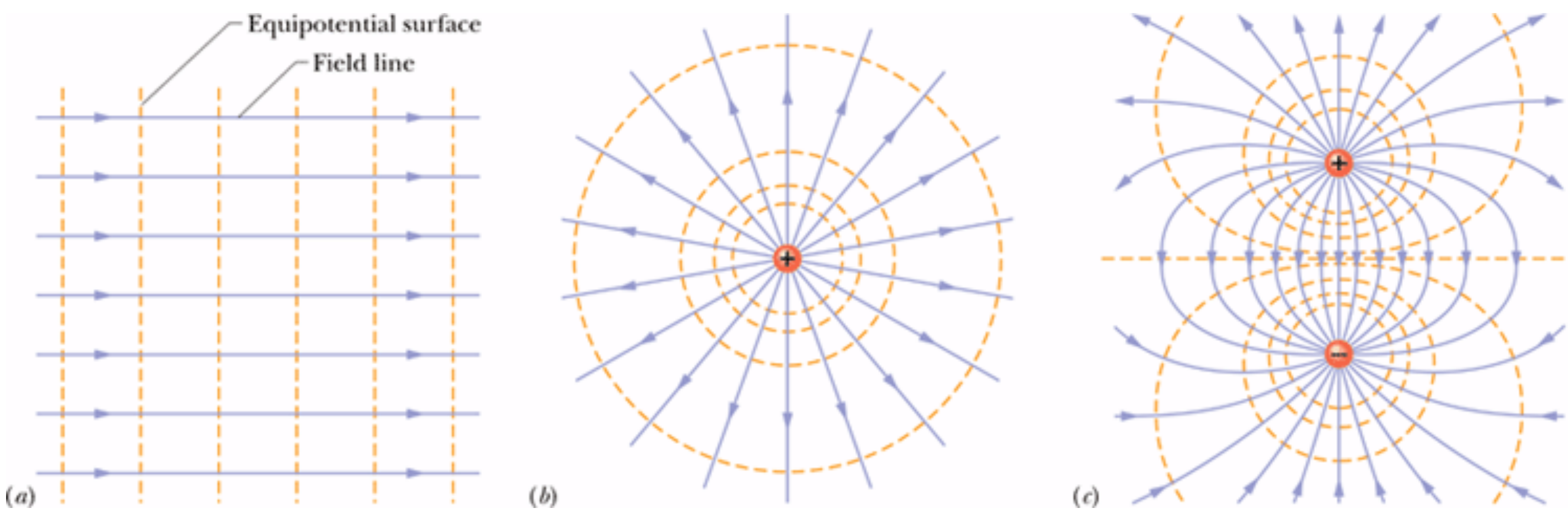
$$dW = -dU = -q_0 dV = 0$$ ***on equipotential surface***

Electric field always points perpendicular to equipotential surface

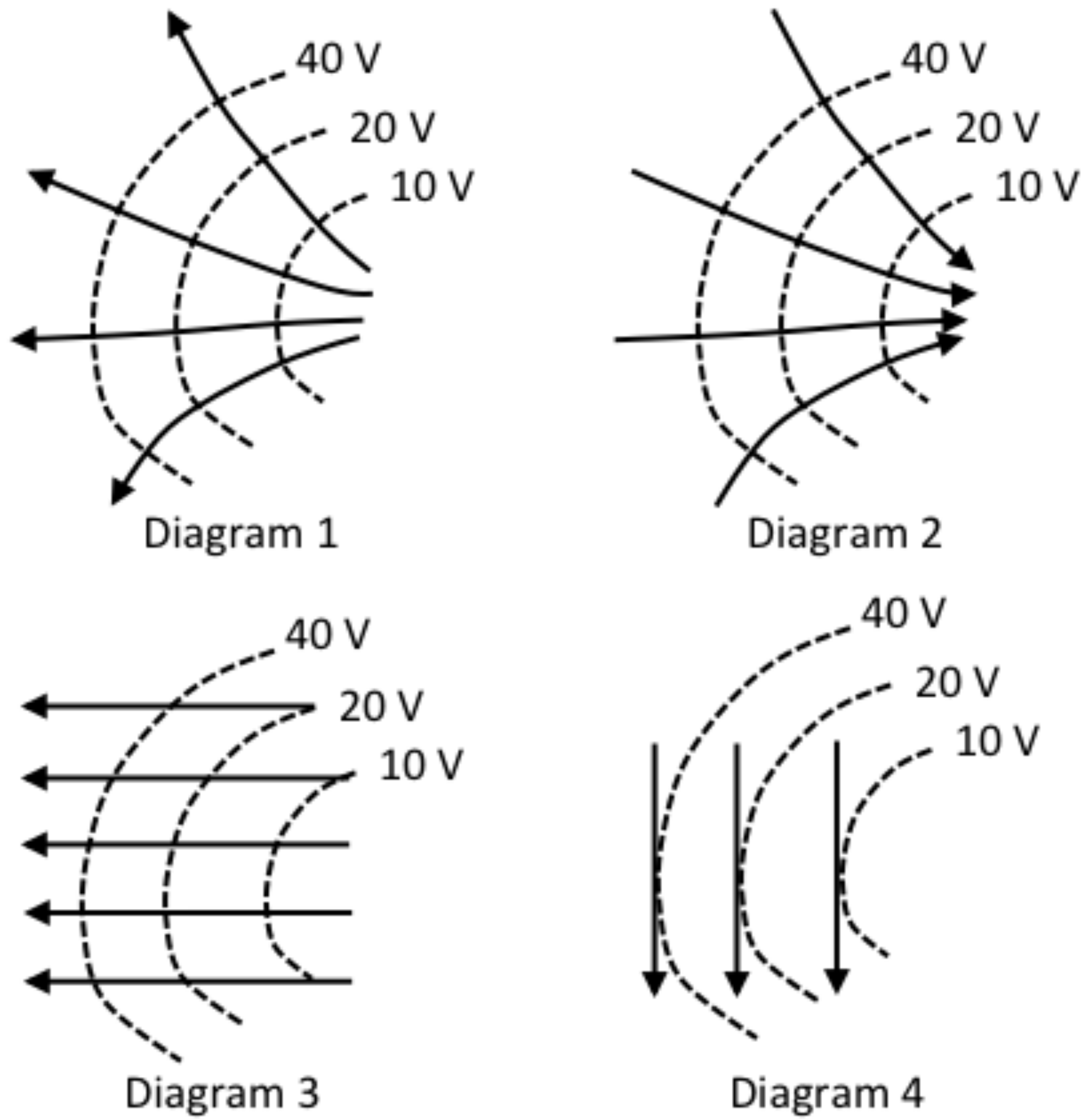
$$dW = -q_0 dV = \vec{F} \bullet d\vec{s} = q_0 \vec{E} \bullet d\vec{s}$$

To find $W = -\Delta U$, we have to integrate $F \cdot ds$ or $qE \cdot ds$

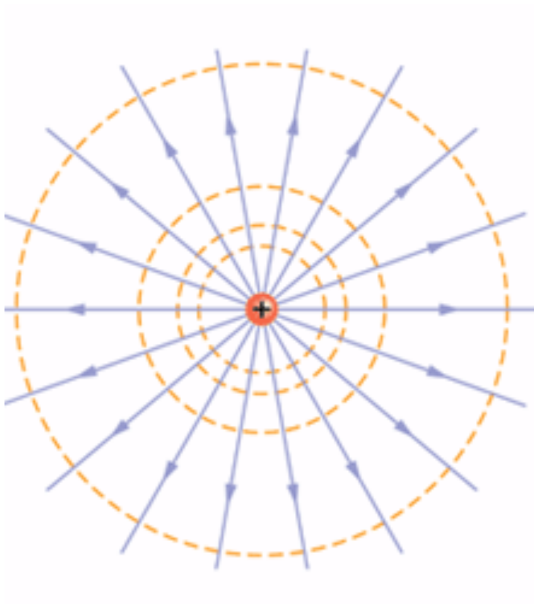
$$W = -\Delta U = U_i - U_f = q_0 \int_i^f \vec{E} \cdot d\vec{s}$$



Which of these diagrams is correct?



Electric potential of a point charge



$$dW = -q_0 dV = q_0 \vec{E} \bullet d\vec{s}$$

$$W = -q_0 \int_i^f dV = q_0 \int_i^f \vec{E} \bullet d\vec{s}$$

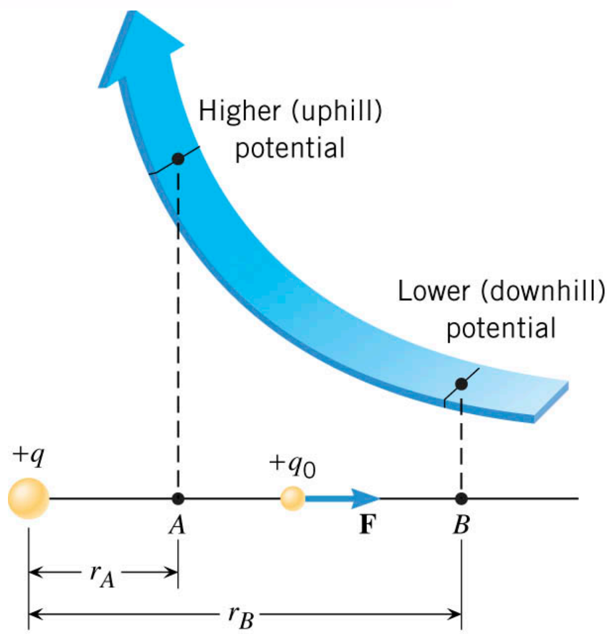
$$V_i - V_f = \int_i^f \vec{E} \bullet d\vec{s}$$

Integrate from distance r away to ∞ (where $V=0$)

$$\vec{E} \bullet d\vec{s} = \left(\frac{1}{4\pi\varepsilon_0} \frac{q}{s^2} \right) ds$$

$$V_r = \frac{q}{4\pi\varepsilon_0} \int_r^\infty \frac{ds}{s^2}$$

$$V_r = -\frac{q}{4\pi\varepsilon_0} \left(\frac{1}{\infty} - \frac{1}{r} \right)$$

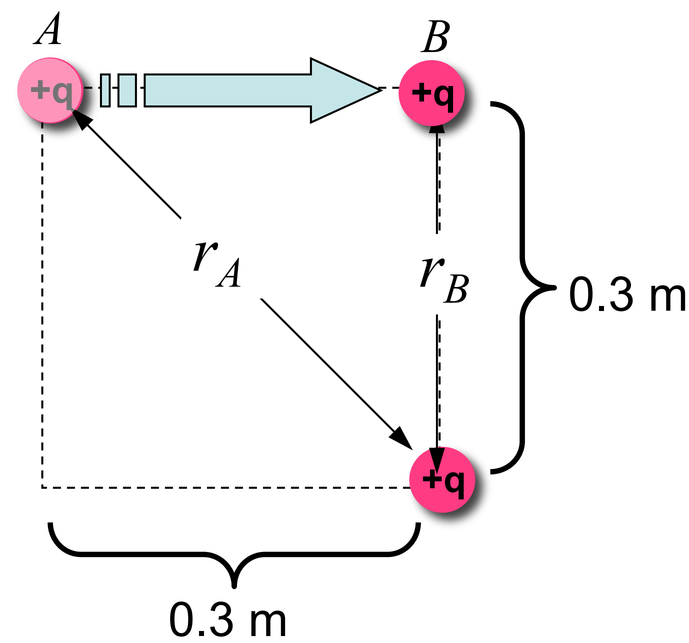


$$V_r = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

Works whether q is + or -

Two charges **(q=5μC)** are arranged at the opposite corners of a square. How much work is done in moving one of the charges to an empty corner?

$$W_{AB} = q_0\left(V_A - V_B\right) = k\frac{q \cdot q_0}{r_A} - k\frac{q \cdot q_0}{r_B}$$



$$r_A = \sqrt{(0.3)^2 + (0.3)^2} = 0.43m$$

$$r_B = 0.3m$$

$$W_{AB} = kq \cdot q_0\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$$

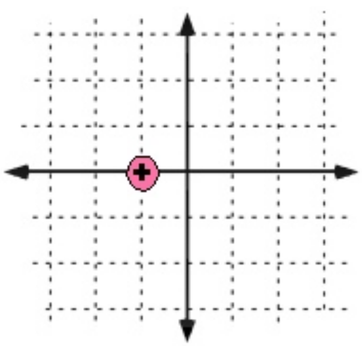
$$W_{AB} = \left(9 \times 10^9 N\frac{m^2}{C^2}\right)\left(5 \times 10^{-6} C\right)\left(5 \times 10^{-6} C\right)\left(\frac{1}{.42m} - \frac{1}{.3m}\right)$$

$W_{AB} = -0.21Nm = -0.21J$ Work is done *by the force* $W = Fd\cos\theta$

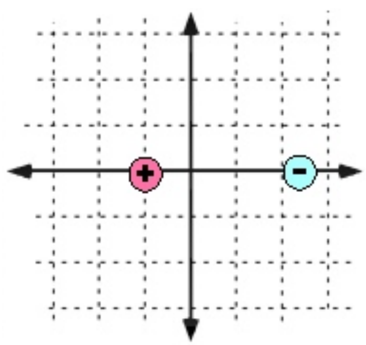
W>0 If the motion is in the same direction of the force

$W = -\Delta PE \Longrightarrow$ PE reduces if $W>0$

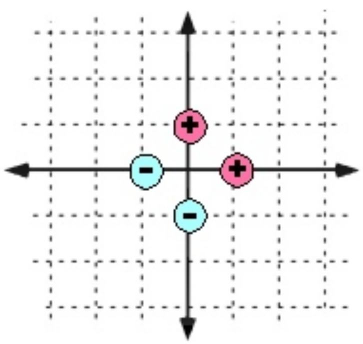
In the scenarios below, red dots represent positive charges and purple dots represent negative charges with the same magnitude. Rank the scenarios by the magnitude of the potential at the origin.



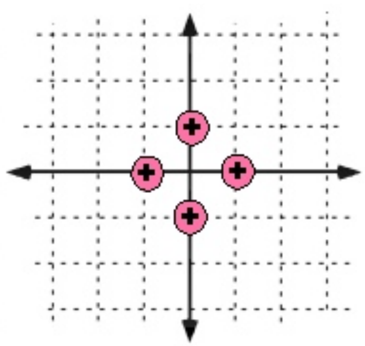
1. Scenario 1



2. Scenario 2



3. Scenario 3



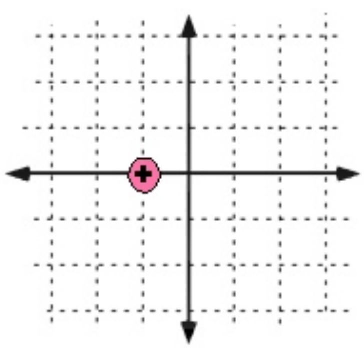
4. Scenario 4

The potential is a scalar field (just a number)

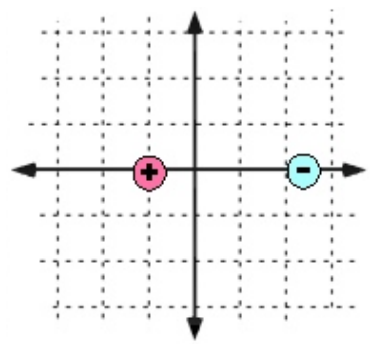
Potential from a distribution of point charges is just the sum of the potential from each charge

$$V_n = \sum_{i=1}^{n} V_i$$

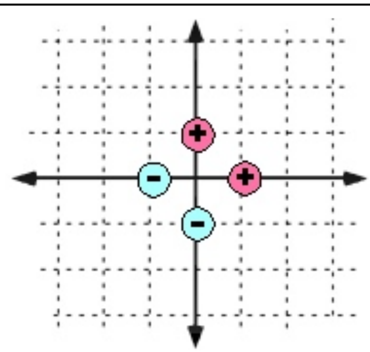
In the scenarios below, red dots represent positive charges and purple dots represent negative charges with the same magnitude. Rank the scenarios by the magnitude of the electric field at the origin.



1. Scenario 1



2. Scenario 2



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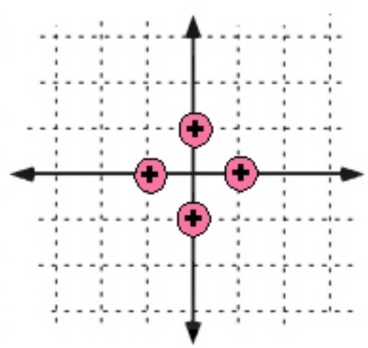
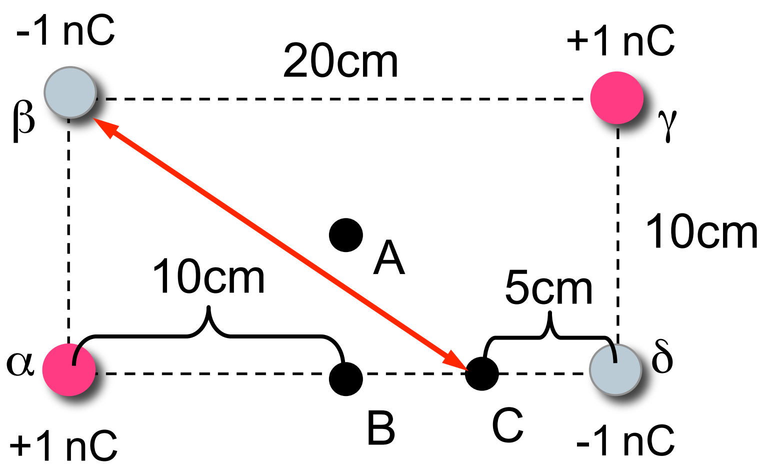


4. Scenario 4

Charges are arranged at the corners of a rectangle as shown, what is the potential at points A, B, and C?



$$V = V_\alpha + V_\beta + V_\gamma + V_\delta$$

$$V_A = k\frac{1nC}{r} + k\frac{(-1nC)}{r} + k\frac{1nC}{r} + k\frac{(-1nC)}{r}$$

$$V_A = 0 \qquad V_B = 0$$

$$r_\beta = \sqrt{10^2 + 15^2} = 18.0cm \qquad r_\gamma = \sqrt{10^2 + 5^2} = 11.2cm$$

$$V_c = k\frac{10^{-9}C}{.15m} + k\frac{(-10^{-9}C)}{.18m} + k\frac{10^{-9}C}{.11m} + k\frac{(-10^{-9}C)}{.05m}$$

$$V_c = k\left(-10.0\times 10^{-9}\frac{C}{m}\right) = -90V$$