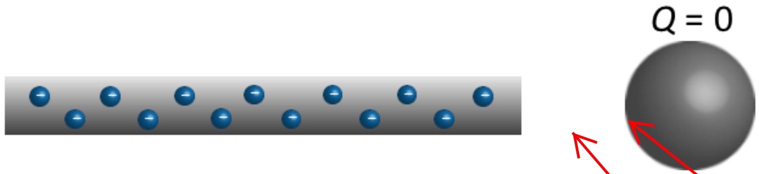
The next two questions pertain to the situation described below.

As shown in the figure, a negatively charged rod is brought close to an uncharged conducting sphere but **does not** touch it.



charge induction, because charges with different signs attract each other.

Note the conservation of charges

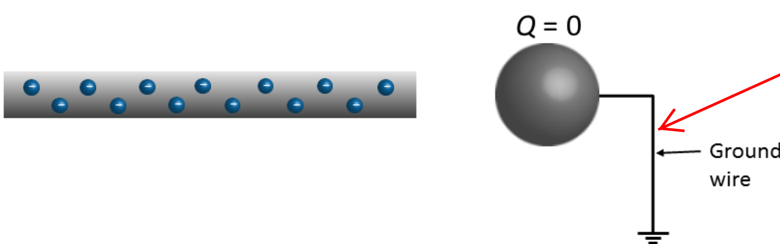
1) Which of the following statements about the sphere is true?

a. The sphere is attracted to the rod.
b. The sphere is repelled by the rod.
c. The sphere experiences no electrical force.

+ is induced

attractive Coulomb force between - and induced +

2) Now a conducting wire touches the sphere, connecting it to the ground while the charged rod remains close to it. What happens after the wire is remove?

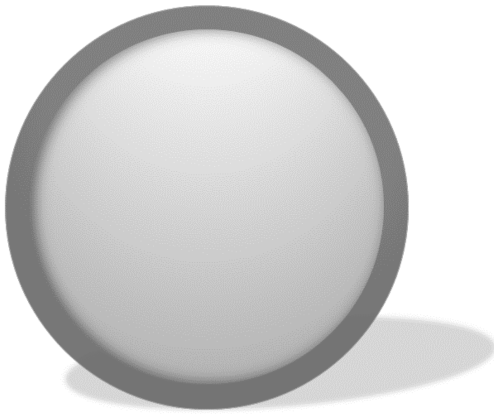


The charges with the same sign try to avoid each other as much as they can!
so the induced negative charge escapes to the earth.

Thus, the sphere is more strongly attracted to the rod than in case 1).

a. The sphere experiences no electrical force.
b. The sphere is repelled by the rod.
c. The sphere is attracted to the rod.

3) Consider an uncharged spherical conducting shell as shown.



Charges with the same sign wish to avoid each other as much as possible, so any charge wishes to get out of the sphere (but can't!).

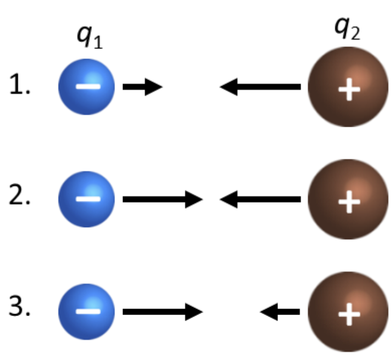
If charges are transferred to it, which statement is TRUE regarding their behavior?

a. They will spread on the inner surface.
b. They will be distributed uniformly throughout the conductor.
c. They will spread on the outer surface.

4) Two charges are placed near each other as shown in the figure.

Which of the following diagrams best depicts the forces acting on the charges? The lengths of the vectors represent the magnitudes.

Think what if the forces have different magnitudes. Put + on one end of a rod and - on the other end. The rod is always pushed in one direction, and you can increase its kinetic energy without bound. A wonderful energy source.
There is no free lunch!

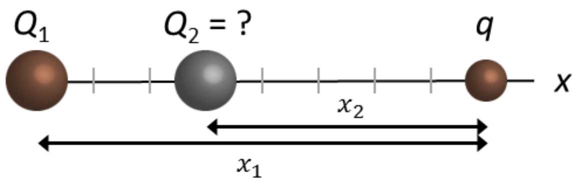


$q_1 = -3$ μC
$q_2 = +11$ μC

a. diagram 1
b. diagram 3
c. diagram 2

The next three questions pertain to the situation described below.

Consider the following arrangement of three charges on one line:



Charges with Positions
$q = +8\ \mu C$
$Q_1 = +2.5\ \mu C$, $x_1 = 8$ cm
Q_2 unknown, $x_2 = 5$ cm

5) What is the <u>absolute value</u> of Q_2 such that the total force on q is zero, i.e., $F_{q,tot} = 0$?

We wish to make the total electric field at the position of q vanish.

a. It is not possible to make the total force on q zero.
b. $|Q_2| = 0.98\ \mu C$
c. $|Q_2| = 8\ \mu C$

kQ1/x_1^2 + kQ2/x_2^2 = 0 -> |Q1|/x_1^2 = |Q2|/x_2^2
-> |Q2| = |Q1|(x_2/x_1)^2 = 2.5 (5/8)^2 = 0.9766

6) Which of the following is true about Q_2 when $F_{q,tot} = 0$:

a. $Q_2 < 0$
b. $Q_2 = 0$
c. $Q_2 > 0$

The signs must be different from Q1.

7) How would your answer for charge Q_2 change if q doubled in charge?

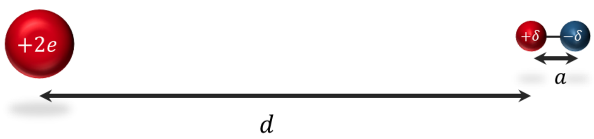
We did not pay any attention to it!

a. Q_2 would increase.
b. Q_2 would remain the same.
c. Q_2 would decrease.

The next two questions pertain to the situation described below.

An electric dipole has a separation distance *a*.

It is placed a distance *d* from a Ca^{2+} ion with charge *2e*.



$a = 1.4$ nm
$d = 2.3\ \mu$m
$e = 1.602 \times 10^{-19}$ C

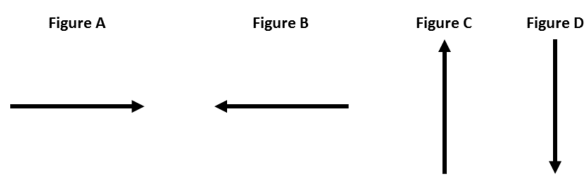
Coulomb's law + superposition principle

8) If $|\delta| = 0.155e$ what is the magnitude of the net force on the dipole due to the ion?

a. $F = 1.6 \times 10^{-20}$ N
b. $F = 0$ N
c. $F = 1.9 \times 10^{-32}$ N
d. $F = 6.2 \times 10^{-29}$ N
e. $F = 2.7 \times 10^{-17}$ N

F = k(2e)[0.155e/d^2 - 0.155e/(d+a)^2]
= 0.301ke^2[1/d^2 - 1/(d+a)^2]
= 0.301 x 9x10^9 x(1.6x10^{-19})^2 [1/(2.3x10^{-6})^2 -1/(2.3014x10^{-6})^2
= 6.935x10^{9-38}[0.0002299x10^{12}]
= 0.001595 x 10^{-17} = 1.595 x 10^{-20} N

9) Which of the diagrams best describes the direction of the net force on the dipole?



++ is closer, so repulsion prevails.

a. None of these
b. Figure C
c. Figure D
d. Figure B
e. Figure A

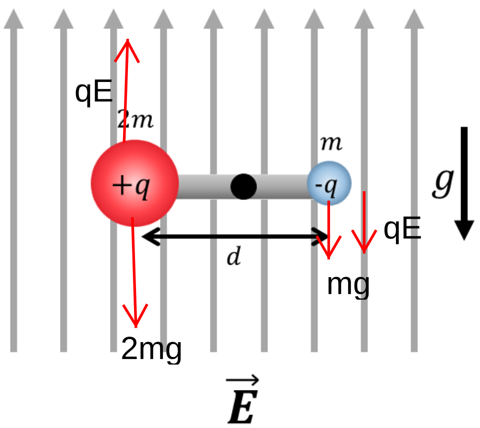
The next two questions pertain to the situation described below.

Consider the horizontal dipole in a uniform, vertical electric field $\vec{\mathbf{E}}$ as shown in the diagram.

The dipole is made from two charges of magnitude $|q|$ separated by a distance d.

The charges have different masses, as shown in the diagram.

The charges can rotate about a pivot at the mid-point between the two charges.



Draw all the forces

Gravity acts as shown in the figure.

$|q| = 8.1\ \mu C$
$d = 0.7$ cm
$m = 2.5$ g

10) What is the <u>magnitude</u> of the electric field, $|\vec{\mathbf{E}}|$, needed to prevent the dipole from rotating?

a. $|\vec{\mathbf{E}}| = 1500$ N/C
b. $|\vec{\mathbf{E}}| = 4500$ N/C
c. $|\vec{\mathbf{E}}| = 2 \times 10^3$ N/C

No rotation, that is, no torque, so forces on the charges must be the same.

2mg - qE = qE + mg -> 2qE = mg or E = mg/2q
E = 2.5x10^{-3}x9.8/2(8.1x10^{-6}) = 1.512 x 10^{-3 + 6}

11) The value of $|q|$ is doubled. To prevent the dipole from rotating, the magnitude of the electric field $|\vec{\mathbf{E}}|$ must

qE must be kept constant. |E| must be halved.

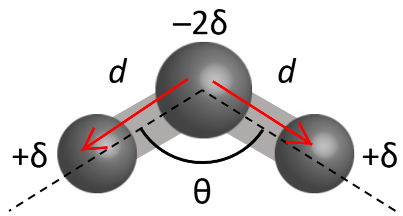
a. remain the same.
b. decrease.
c. increase.

12) A molecule consists of three atoms arranged at an angle $\theta = 120^\circ$ as shown in the figure.

The atoms have partial charges, as shown in the figure, $\delta = +0.15e$ ($e = 1.602 \times 10^{-19}$ C).

The bond length is $d = 1.6 \times 10^{-10}$ m.

We can decompose this into two identical dipole moments.



This means the total dipole moment has the same magnitude as that of one of the red arrow

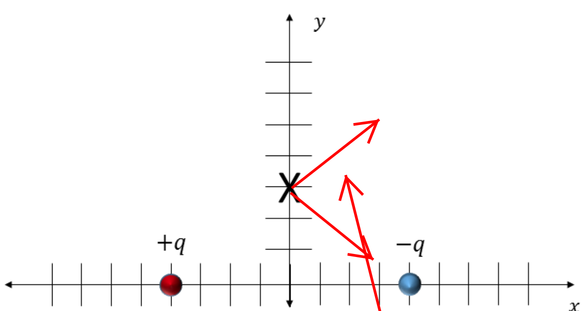
Determine the <u>magnitude</u> of the net electric dipole moment, $|\vec{p}|$, of the molecule.

|p| = d x delta = 1.6x10^{-10} x 0.15 x 1.6x10^{-19}
= 0.384 x 10^{-10-19} = 3.84 x 10^{-30}

a. $|\vec{p}| = 0$ C·m
b. $|\vec{p}| = 1.2 \times 10^{-29}$ C·m
c. $|\vec{p}| = 3.8 \times 10^{-30}$ C·m
d. $|\vec{p}| = 2.5 \times 10^{-30}$ C·m
e. $|\vec{p}| = 8.4 \times 10^{-30}$ C·m

The next two questions pertain to the situation described below.

Consider the pair of charges placed on the x-axis as shown in the diagram. The red charge, <u>on the left</u>, is positive. The blue charge, <u>on the right</u>, is negative.



Use superposition principle
Sketch the individual E.

It is obvious the E is in the x-direction.

$|q| = 6.7\ \mu$C

Positions:
The positive charge (red): $x = -4$ cm
The negative charge (blue): $x = 4$ cm
X: (0 cm, 3 cm)

Pythagoras used

13) What is the magnitude of the net electric field $\vec{\mathbf{E}}$ at the point (0 cm, 3 cm)?

a. $|\vec{\mathbf{E}}| = 2.9 \times 10^7$ N/C
b. $|\vec{\mathbf{E}}| = 3.9 \times 10^7$ N/C
c. $|\vec{\mathbf{E}}| = 0$ N/C
d. $|\vec{\mathbf{E}}| = 2.4 \times 10^7$ N/C
e. $|\vec{\mathbf{E}}| = 160$ N/C

Its magnitude E is kq/r^2 = 9x10^9 x 6.7x10^{-6}/(5x10^{-2})^2
= 2.412 x 10^{9-6+4} = 2.412 x 10^{7}

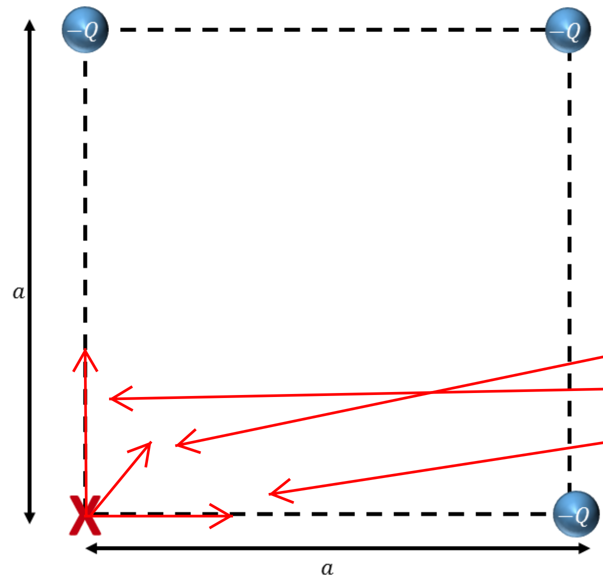
Its x-component is E(4/5).
Hence, the total electric field in the x-direction must have magnitude 8E/5
= 3.859 x 10^7.

14) The net electric field $\vec{\mathbf{E}}$ is directed

a. along a combination of the x-axis and y-axis.
b. along the x-axis only.
c. along the y-axis only.

The next two questions pertain to the situation described below.

Three identical **negative** point charges, each with charge $-Q$, are placed at the corners of a square as shown in the diagram. The edge length of the square is a.



Superposition principle

Sketch individual contributions

kQ/(sqrt{2}a)^2 = kQ/2a^2

magnitudes identical and kQ/a^2

15) What is the magnitude of the electric field, $|\vec{E}|$, at the red X?

a. $|\vec{E}| = \frac{3\sqrt{2}kQ}{a^2}$

b. $|\vec{E}| = \frac{\sqrt{2}}{2}\frac{kQ}{a^2}$

c. $|\vec{E}| = \frac{(2\sqrt{2}-1)kQ}{2a^2}$

d. $|\vec{E}| = \frac{3}{2}\frac{kQ}{a^2}$

e. $|\vec{E}| = \frac{(2\sqrt{2}+1)kQ}{2a^2}$

Therefore, E is along the diagonal direction and its magnitude must be the sum of kQ/2a^2 and kQ/a^2 times 2cos 45 = sqrt{2}kQ/a^2

16) If all of the charges are changed from $-Q$ to $+Q$ the magnitude of the electric field at the red X will

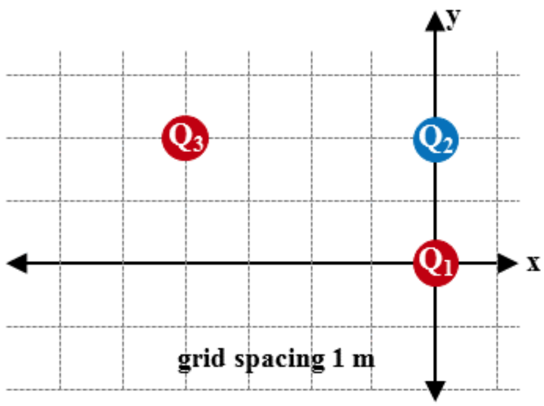
a. increase.

b. decrease.

c. remain the same.

The next two questions pertain to the situation described below.

Three charges are fixed in position as shown in below.



Q_1 =3.1 × 10^{-6} C
Q_2 = -6.2 × 10^{-6} C
Q_3 = 3.1 × 10^{-6} C

superposition principle
pairwise decomposition

The stored energy is the work done to the field.

17) What is the absolute value of the work done by the **electric field** when the charges are brought from infinitely far away to their location in the figure?

a. $|W_E|$ = 0.11 J
b. $|W_E|$ = 0.024 J
c. $|W_E|$ = 0 J

kQ1Q2/r12 + kQ2Q3/r23 + kQ3Q1/r13
=9x10^9[3.1x(-6.2)/2 + (-6.2)(3.1)/4 + 3.1^1/sqrt(4+16)] x 10^{-12}
= -110.4 x 10^{9-12}

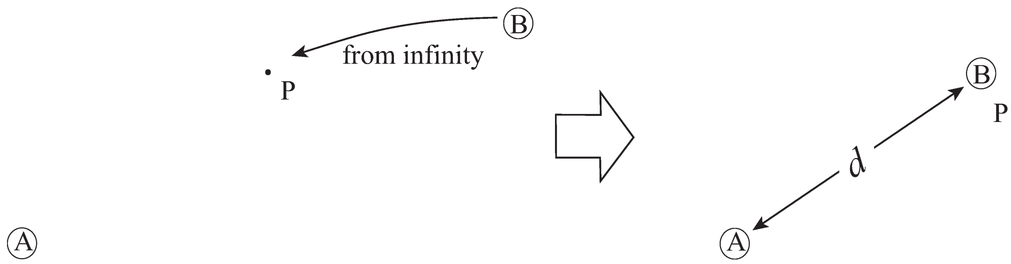
18) What is the sign of the work done by the **electric field** when the charges are brought from infinitely far away to their location in the figure?

a. neither
b. negative
c. positive

The initial energy is 0, and after the charge system in the figure is constructed, the stored energy is negative. This means the system (or the field) `paid' a positive work.

The next two questions pertain to the situation described below.

A 19 μC positive point charge A is fixed in space.



This is a simplified repetition of 17.

19) You bring another positive point charge B of 5 μC from infinity to a point P which is d =0.2 m away from charge A. How much work do you have to do? (Assume that there are only these two charges.)

a. 4.27 J
b. 10.7 J
c. 14.4 J
d. 1.88 J
e. 2.3 J

kQAQB/d^2 = 9x10^9 x 19x10^{-6} x 5x10^{-6}/0.2
= 4275 x 10^{9-12} = 4.28 J

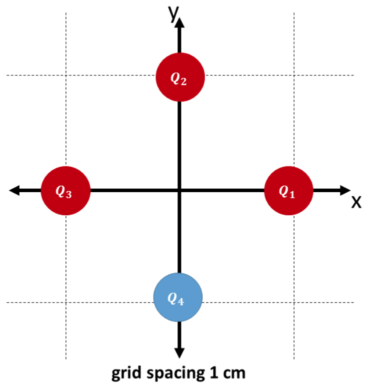
20) Now, charge B is fixed, but charge A is free to move. What is the kinetic energy of charge A after a very long time?

a. Less than the work done by you to move in charge B.
b. Greater than the work done by you to move in charge B.
c. The same as the work done by you to move in charge B.

Conservation of energy. The total potential energy is all converted into K.

The next four questions pertain to the situation described below.

Four charges of equal magnitude are arranged in the coordinate system as shown.



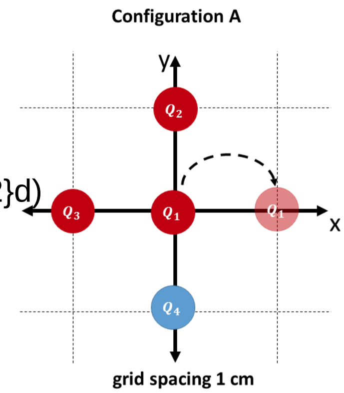
The charge values and locations are:

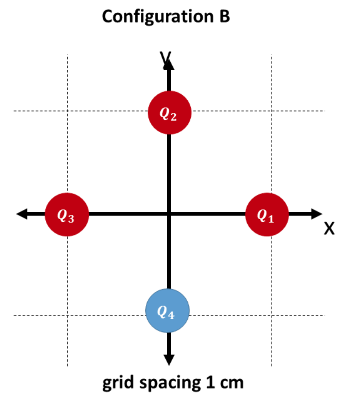
Q_1 = 8 μC, located at (1 cm, 0 cm)
Q_2 = 8 μC, located at (0 cm, 1 cm)
Q_3 = 8 μC, located at (−1 cm, 0 cm)
Q_4 = -8 μC, located at (0 cm, −1 cm)

This is not a good preamble.

21) What is the <u>absolute value</u> of the work **you** do moving Q_1 from the origin (Configuration A) to its final position at (1 cm, 0 cm) (Configuration B)?

W = U_after - U_before, because of conservation of energy.





U_before = kq^2(1/d+1/d-1/d)= kq^2/d
U_after = kq^2(1/2d + 1/sqrt{2}d =1/sqrt{2}d)
= kq^2/2d.
Therefore,
W = -kq^2/2d
= - 9x10^9 (8x10^{-6})^2/2(0.01)
= -288 x 10^{9-12+2} = -28.8 J

a. $|W_{you}| = 0$ J
b. $|W_{you}| = 58$ J
c. $|W_{you}| = 29$ J

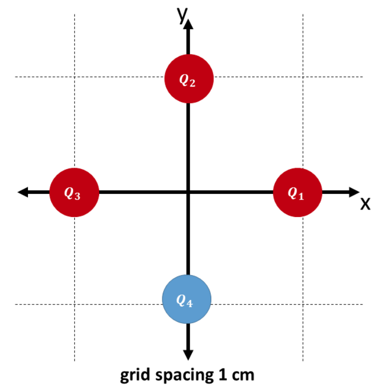
22) The <u>sign</u> of the work **you** do moving Q_1 from the origin (Configuration A) to its final position at (1 cm, 0 cm) (Configuration B) is

Since the system loses energy, you are DONE a positive work. That is, you DO a negative work.

a. neither.
b. negative.
c. positive.

23) Calculate the absolute value of the electrical potential at the origin for the charges in the configuration shown.

Use superposition principle



V = kq(3/d-1/d) = 2kq/d
= 2 x 9x10^9 x 8 x 10^{-6}/(0.01) = 144 x 10^{9-6+2}
= 1.44 x 10^{13-6} The sign is correct.

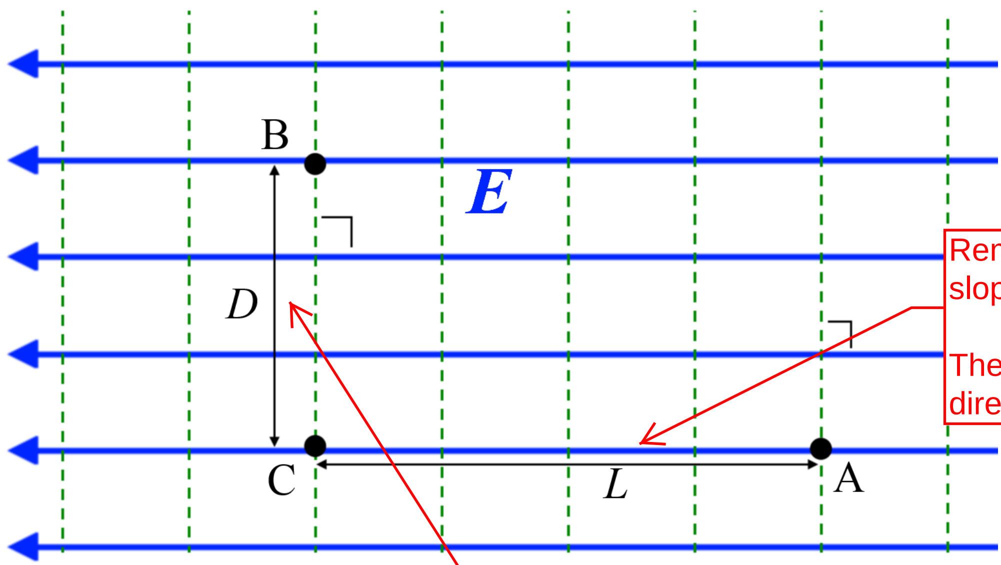
a. $|V(0, 0)| = 0$ V
b. $|V(0, 0)| = 1.4 \times 10^7$ V
c. $|V(0, 0)| = 2.9 \times 10^7$ V

24) The sign of the electrical potential at the origin for the configuration in the diagram is

a. negative.
b. neither.
c. positive.

The next three questions pertain to the situation described below.

The following figure describes a uniform electric field **E** with magnitude E. The dashed lines denote planes perpendicular to the field.



They denote equipotential contours.

Remember that E is the (negative) slope of the landscape of V.

Therefore, E points the downhill direction, so A is higher than C or B.

25) What is the magnitude of the electric potential difference $\Delta V = V_B - B_A$ between B and A in the figure?

a. EL
b. ED
c. $E(D + L)$

No potential cahge

26) Which statement is true about $\Delta V = V_B - B_A$ between B and A in the figure?

a. $\Delta V = 0$
b. $\Delta V < 0$
c. $\Delta V > 0$

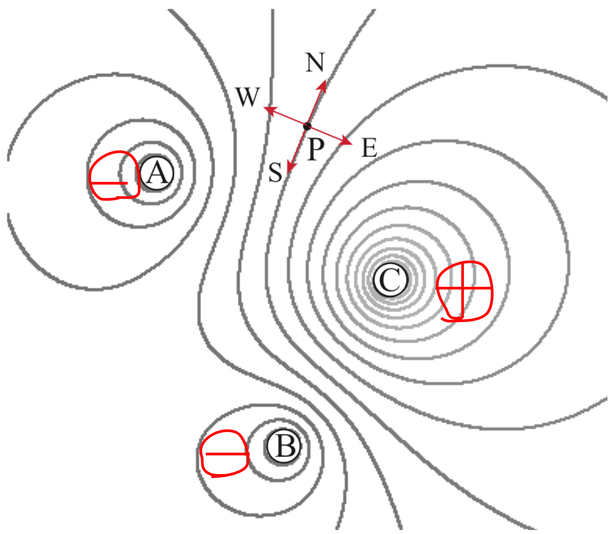
27) A charge Q is placed initially at B. You drag the charge along the edges of the triangle ABC clockwise and return it to point B. What is the total work W that you have to do?

a. $W > 0$
b. $W < 0$
c. $W = 0$

Your `height' remain the same as before, so no work is needed.

The next two questions pertain to the situation described below.

There are three charges A , B, and C on the plane. The equipotential curves are described in the following figure.
Charge A is negative.



A and C can easily connected by force lines, so they must have opposite signs.

The same statement hold for BC, so A and B must have the same sign.

28) Choose the correct statement about the signs of charges in the figure from below.

a. There are two positive charges, B and C.
b. The only positive charge in the figure is B.
c. The only positive charge in the figure is C.
d. There is not enough information to decide the signs of the charges in the figure.
e. There is no positive charge.

29) At point P, choose the correct direction of the electric field.

Electric field vector indicates the steepest down hill direction, so it must be orthogonal to the equipotential contours.

a. S
b. E
c. None of the four specified directions.
d. W
e. N