We have used Force, Work, and Potential energy in Mechanics. Force x Distance = Work done and that changes the Potential Energy. If the direction of the ***External*** Force and the direction of the distance moved (both vectors) are parallel (or have a component parallel) then the work decreases and so does the Potential Energy. There is a plus or minus sign in the definition, depending on who is doing the work.

Work = $(\text{Force})_{\text{by me}}$ x distance x cos $(\theta_{\text{between force and distance}})$ where θ is the angle between the two vectors. When I push, when the vectors are parallel, $\theta = 0$ degrees, the Work I do is ***positive*** and when they are anti-parallel (180 degrees), the Work I do is ***negative***.

If an EXTERNAL force, such as gravity, is parallel to the direction of motion, gravity does the work.

In general, we have a result for the Work, or the change in Potential Energy, a number which can be negative or positive. If we, as outsiders do the work, the Potential Energy is positive. If an outside source does the work, the Potential Energy is negative. In other words, if I do the work, the energy of the system increases. If the system does the work, then its energy decreases.

Notice I speak of the SYSTEM. In F = ma, we isolate objects and consider them one at a time. With Energy we consider a system of objects, an object and its environment, Me and the Object I push for example.

In one sense, gravity is “easy” as mass is always positive, so moving a mass in a direction opposite to the gravitational force increases the Gravitational Potential Energy and vice versa.

But for electricity, where there are both attractive and repulsive forces, Electrical Potential Energy depends BOTH on the charges creating the field and on the charges experiencing the field. I want a quantity which depends ONLY on the charge creating the field. So I divide the Potential Energy by the value of the charge being moved and get a term which depends ONLY on the charge that creates the field.

If the charge creating the field is positive, and I move a positive charge, it will increase if I approach the positive charge, and decrease if I move away. If the charge creating the field is negative and I move a positive charge, the result is exactly the opposite. The answer depends on the sign of the charge that I move. Therefore, we DIVIDE the Electrical Potential Energy by the value and sign of the charge that I am moving.

We call this quantity the POTENTIAL, Potential Energy change divided by the sign of the charge that gets moved.

The unit of Potential, which is Joules/Coulomb, we call VOLTS.

Positive charges create fields that point away from them. Moving a negative charge away from the charges creating such a field takes work from us (against an attractive force) Thus the potential energy INCREASES but the potential DECREASES as I divide this Positive PE by the negative charge moved.

Moving a positive charge away from this same field does not take work, the charges move by themselves. Thus the Potential Energy decreases (and the Kinetic Energy would increase). Dividing by a positive charge then gives a Potential that decreases. Potential always decreases when moving away from a positive charge, no matter the sign of the charge being moved.

We could make the exact same argument for a negative charge creating a field. Moving away increases Potential.

$$\text{The change in Potential} = \frac{\text{The change in Potential Energy}}{\text{Charge moved}}$$

$$\Delta V = \frac{\Delta(PE)}{q}$$

The **Δ** symbol meaning the Change of Potential Energy and the Change in Voltage.

The Electric Field of a ***point charge*** is easily found from Coulomb's Law.

$$F = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}$$

$$E = \frac{F}{q_2} = k\frac{q_1}{r^2} = \frac{1}{4\pi\varepsilon_o}\frac{q_1}{r^2}$$

The Potential of a ***point charge*** is then

$$V = k\frac{q_1}{r} = \frac{1}{4\pi\varepsilon_o}\frac{q_1}{r}$$

Electric Fields and Potential for other charge distributions are different!!

The great advantage in working with Energy as opposed to Force is that Energy is a scalar, just a number, whereas Force is a Vector and the maths are more difficult.

The advantage of working with Electric Potential is that it is a scalar, independent of the sign of the charge moved. Electric Field, however, is a vector, pointing away from positive charges and towards negative ones. Vectors are more difficult to work with than scalars.

If 500 J of work are required to carry a 40 C charge form one point to another, the potential difference between these two points is:

A) 12.5 V
B) 20,000 V
C) 0.08 V
D) depends on the path
E) none of these

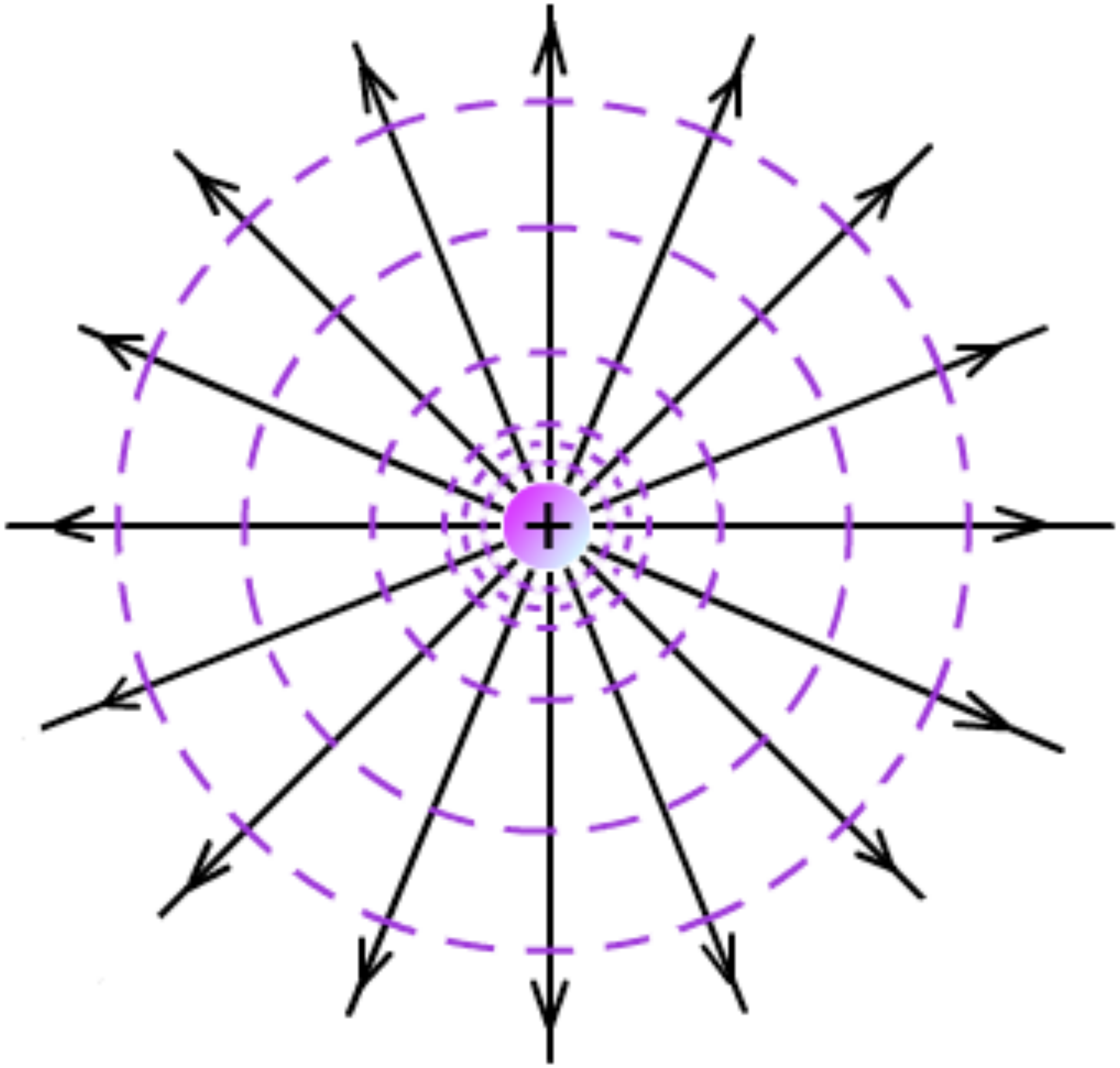
Electric Field, like Force is a vector. Potential, like Potential Energy is a scalar.

Regions where the Potential is constant can be connected and then drawn in space. On a two-dimensional piece of paper, they look like lines. Such lines are called EQUIPOTENTIALS, (or Lines of Equal Potential).

The Electric Field Vectors in space at an equipotential surface, or line, will be perpendicular to that surface in 3-D, or to the line in 2-D.

Remember

$$\Delta V = \frac{\Delta(PE)}{q}$$



Point Charge with Field Lines and Equipotentials

If we move a positive charge to a positively charged metal plate, the potential ***energy*** of the charge is

A. decreased

B. increased

C. remains constant

D. dissipated

If we move a positive charge to a positively charged metal
plate, the potential of the charge is

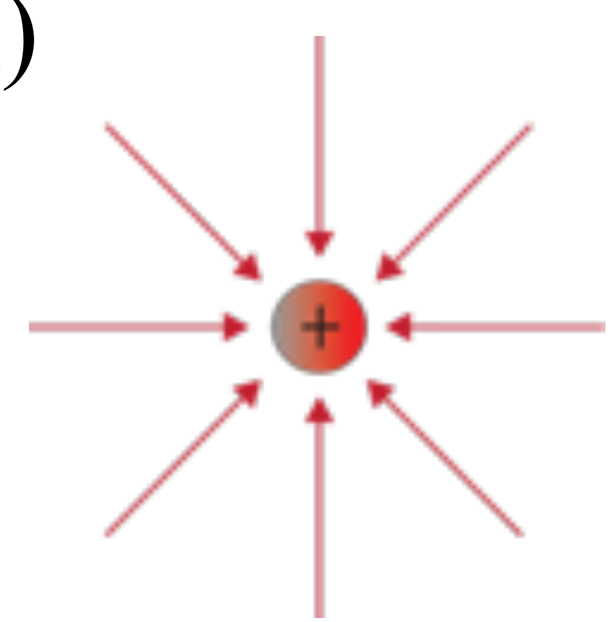
A. decreased

B. increased

C. remains constant

D. dissipated

A)



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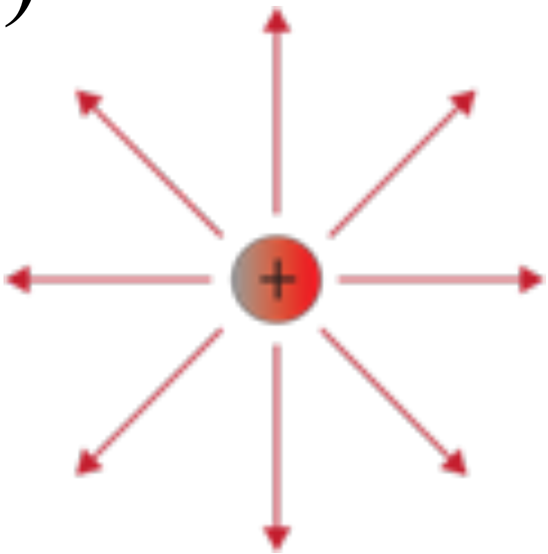

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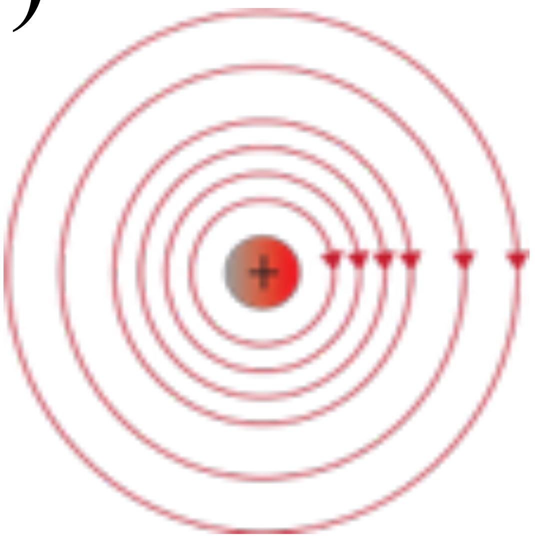
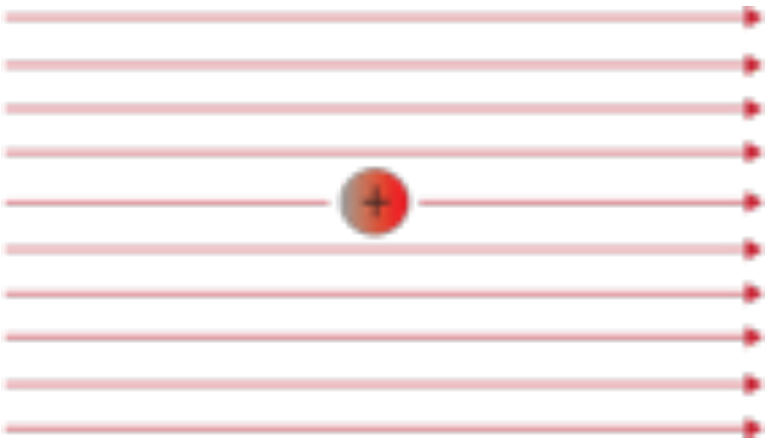
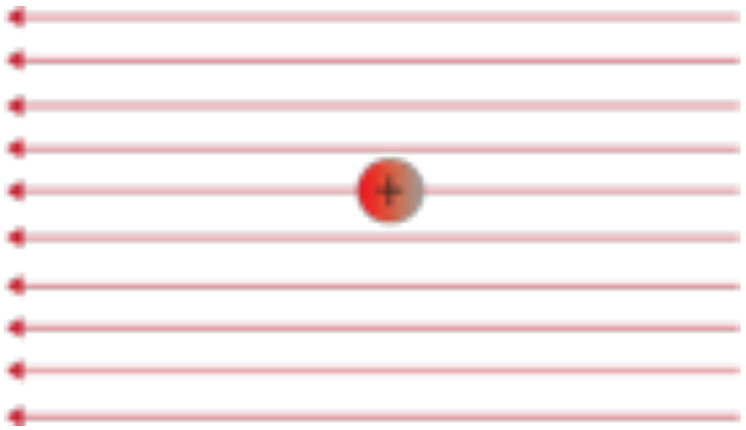


D)



E)



Which of these drawings represents the electric field map due to a single positive charge?

If we move a negative charge to a positively charged metal plate, the potential ***energy*** of the charge is

A. decreased

B. increased

C. remains constant

D. dissipated

If we move a negative charge to a positively charged metal plate, the potential of the charge is

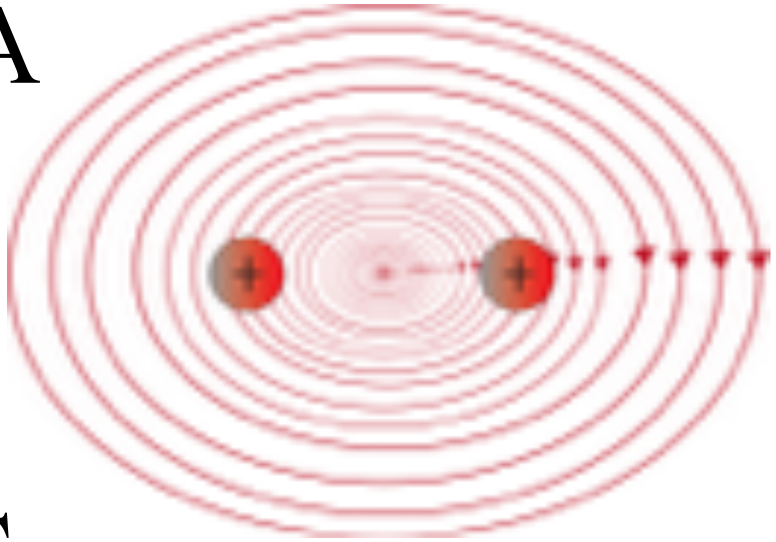
A. decreased

B. increased

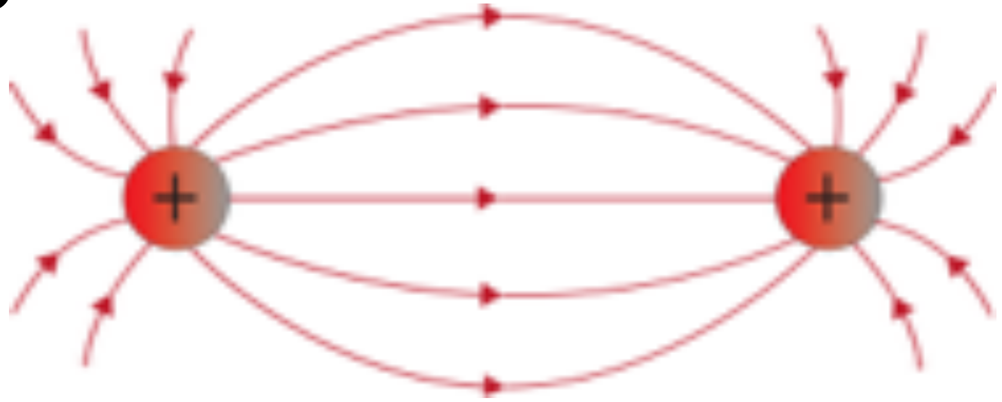
C. remains constant

D. dissipated

A



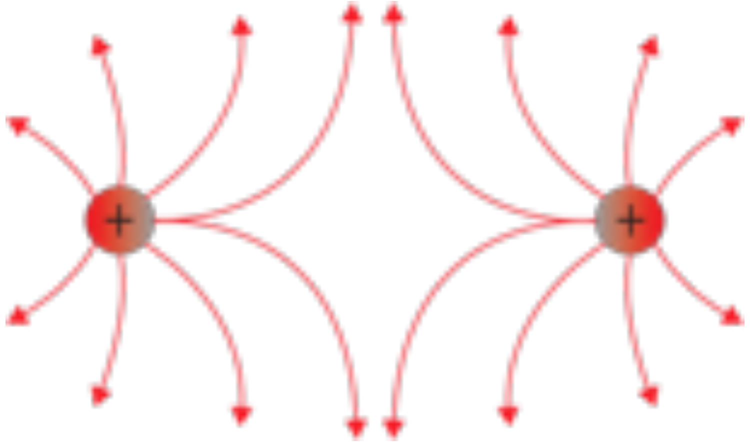
B



C

D

E



Which of the following represents the electric field map due to a combination of two positive charges?

Compare the Gravitational Field and the Electric Field produced by a proton.

A) The Gravitational Field is the same strength as the Electric Field.

B) The Electric Field is stronger and is in the same direction as the Gravitational Field.

C) The Electric Field is stronger and in the opposite direction of the Gravitational Field.

D) The Gravitational Field is stronger and is in the same direction as the Electric Field.