26 The Electric Field

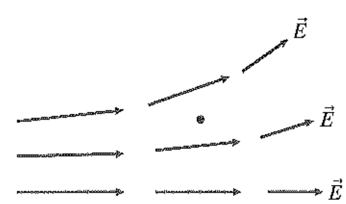
Workbook and TIPERS

26.1 Electric Field Models

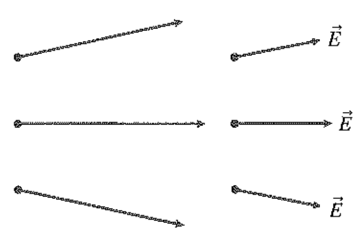
26.2 The Electric Field of Multiple Point Charges

1. You've been assigned the task of determining the magnitude and direction of the electric field at a point in space. Give a step-by-step procedure of how you will do so. List any objects you will use, any measurements you will make, and any calculations you will need to perform. Make sure that your measurements do not disturb the charges that are creating the field.

2. Is there an electric field at the position of the dot? If so, draw the electric field vector on the figure. If not, what would you need to do to create an electric field at this point?



3. This is the electric field in a region of space.



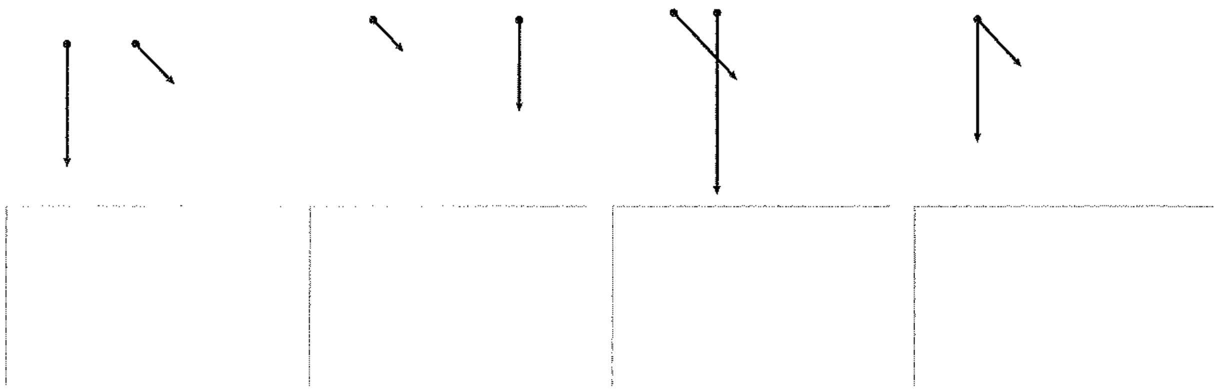
   a. Explain the information that is portrayed in this diagram.

   b. If field vectors were drawn at the same six points but each was only half as long, would the picture represent the same electric field or a different electric field? Explain.

4. Each figure shows two vectors. Can a point charge create an electric field that looks like this at these two points? If so, add the charge to the figure. If not, why not?

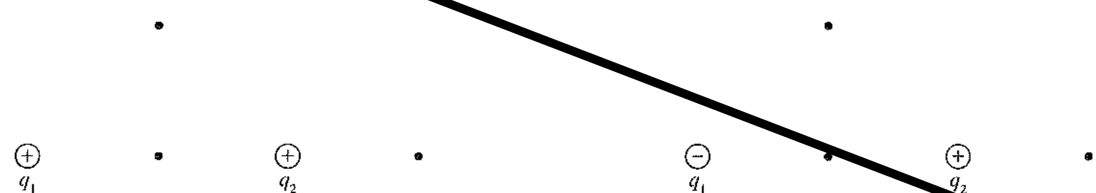
   Note: The dots are the points to which the vectors are attached. There are no charges at these points.

a. b. c. d.



5. At each of the dots, use a **black** pen or pencil to draw and label the electric fields $\vec{E}_1$ and $\vec{E}_2$ due to the two point charges. Make sure that the *relative* lengths of your vectors indicate the strength of each electric field. Then use a **red** pen or pencil to draw and label the net electric field $\vec{E}_{net}$ at each dot.

a. b.



6. For each of the figures, use dots to mark any point or points (other than infinity) where $\vec{E} = \vec{0}$.

a.

b.

7. Compare the electric field strengths E_1 and E_2 at the two points labeled 1 and 2. For each, is $E_1 > E_2$, is $E_1 = E_2$, or is $E_1 < E_2$?

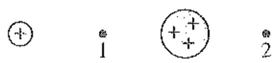
a.

b.

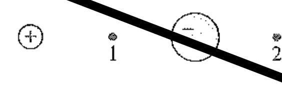
c.

d.

e.

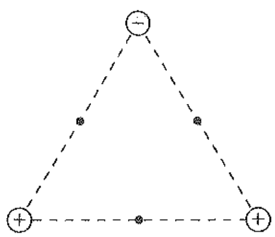


f.

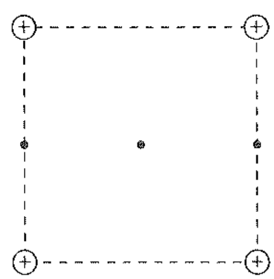


8. For each figure, draw and label the net electric field vector $\vec{E}_{net}$ at each of the points marked with a dot or, if appropriate, label the dot $\vec{E}_{net} = \vec{0}$. The lengths of your vectors should indicate the magnitude of $\vec{E}$ at each point.

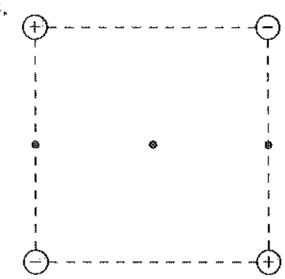
a.



b.

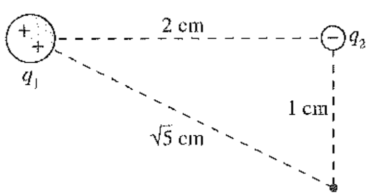


c.



9. At the position of the dot, draw field vectors $\vec{E}_1$ and $\vec{E}_2$ due to q_1 and q_2, and the net electric field $\vec{E}_{net}$. Then, in the blanks, state whether the x- and y-components of $\vec{E}_{net}$ are positive or negative.

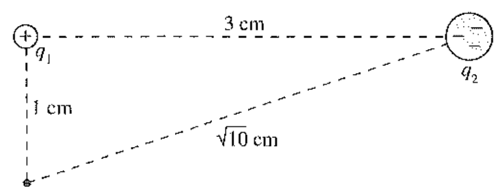
a.



$(E_{net})_x$ ______

$(E_{net})_y$ ______

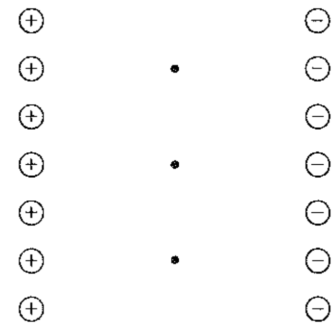
b.



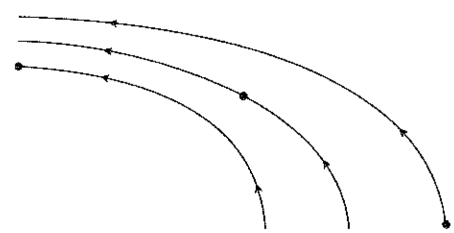
$(E_{net})_x$ ______

$(E_{net})_y$ ______

10. Draw the net electric field vector at the three points marked with a dot.
    Hint: Think of the charges as horizontal positive/negative pairs, then use superposition.



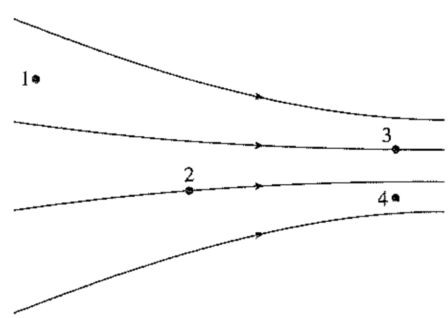
11. The figure shows the electric field lines in a region of space. Draw the electric field vectors at the three dots. The length of the vector should indicate the relative strength of the electric field at that point.



12. The figure shows the electric field lines in a region of space. Rank in order, from largest to smallest, the electric field strengths E_1 to E_4 at points 1 to 4.

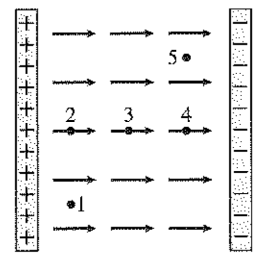
Order:

Explanation:



26.5 The Parallel-Plate Capacitor

21. Rank in order, from largest to smallest, the electric field strengths E_1 to E_5 at each of these points.



Order:

Explanation:

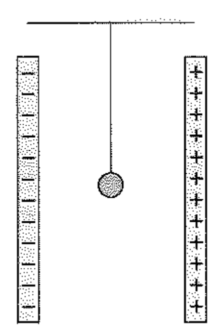
22. A parallel-plate capacitor is constructed of two square plates, size $L \times L$, separated by distance d. The plates are given charge $\pm Q$. What is the ratio E_f/E_i of the final electric field strength E_f to the initial electric field strength E_i if:

a. Q is doubled?

b. L is doubled?

c. d is doubled?

23. A ball hangs from a thread between two vertical capacitor plates. Initially, the ball hangs straight down. The capacitor plates are charged as shown, then the ball is given a small negative charge. The ball moves to one side, but not enough to touch a capacitor plate.



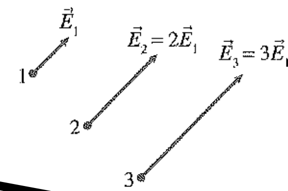
a. Draw the ball and thread in the ball's new equilibrium position.

b. In the space below, draw a free-body diagram of the ball when in its new position.

26.6 Motion of a Charged Particle in an Electric Field

26.7 Motion of a Dipole in an Electric Field

24. A small positive charge q experiences a force of magnitude F_1 when placed at point 1. In terms of F_1:



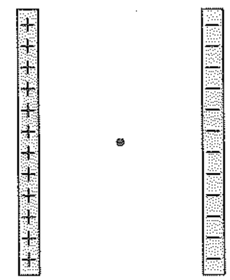
a. What is the force on charge q at point 3? ____________

b. What is the force on a charge $3q$ at point 1? ____________

c. What is the force on a charge $2q$ at point 2? ____________

d. What is the force on a charge $-2q$ at point 2? ____________

25. A small object is released from rest in the center of the capacitor. For each situation, does the object move to the right, to the left, or remain in place? If it moves, does it accelerate or move at constant speed?



a. Positive object.

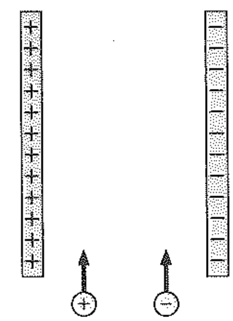
b. Negative object.

c. Neutral object.

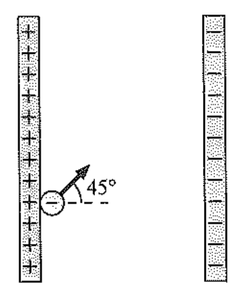
26. Positively and negatively charged objects, with equal masses and equal quantities of charge, enter the capacitor in the directions shown.

a. Use solid lines to draw their trajectories on the figure if their initial velocities are fast.

b. Use dashed lines to draw their trajectories on the figure if their initial velocities are slow.



27. An electron is launched from the positive plate at a 45° angle. It does not have sufficient speed to make it to the negative plate. Draw its trajectory on the figure.



28. First a proton, later an electron are released from rest in the center of a capacitor.

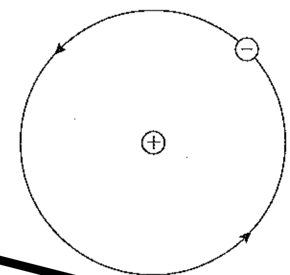
    a. Compare the forces on the two charges. Are they equal, or is one larger? Explain.

    b. Compare the accelerations of the two charges. Are they equal, or is one larger? Explain.

29. The figure shows an electron orbiting a proton in a hydrogen atom.

    a. What force or forces act on the electron?

    b. Draw and label the following vectors on the figure: the electron's velocity $\vec{v}$ and acceleration $\vec{a}$, the net force $\vec{F}_{net}$ on the electron, and the electric field $\vec{E}$ at the position of the electron.



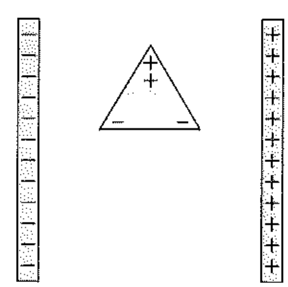
30. Does a charged particle always move in the direction of the electric field? If so, explain why. If not, give an example that is otherwise.

31. Three charges are placed at the corners of a triangle. The ++ charge has twice the quantity of charge of the two – charges; the net charge is zero.

    a. Draw the force vectors on each of the charges.

    b. Is the triangle in equilibrium? __________ If not, draw the equilibrium orientation directly beneath the triangle that is shown.

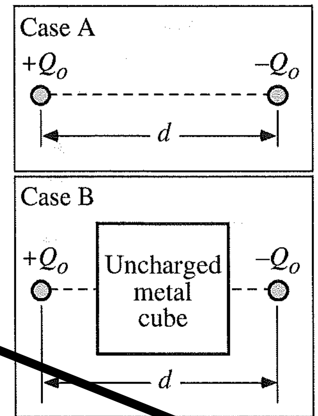
    c. Once in the equilibrium orientation, will the triangle move to the right, move to the left, rotate steadily, or be at rest? Explain.



Name:________________________

D1-CT29: CONDUCTING CUBE BETWEEN POINT CHARGES—NET FORCE

In both cases, two particles with equal and opposite charges are fixed in place a distance d apart. The cases are identical, except that in Case B an uncharged metal cube is placed between the two particles.

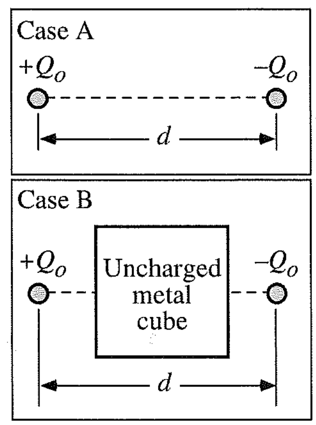


Is the net electric force on the positively charged particle (i) *greater in* Case A, (ii) *greater* in Case B, or (iii) *the same* in both cases? _____

Explain your reasoning.

D1-QRT30: CUBES BETWEEN POINT CHARGES—FORCE EXERTED BY ONE CHARGE ON THE OTHER

In both cases, two equal and opposite charges are fixed in place a distance d apart. The cases are identical, except that in Case B an uncharged metal cube is placed between the two charges.



(a) Will the force exerted on the positive charge by the negative charge be (i) *greater* in Case A, (ii) *greater* in Case B, or (iii) *the same* in both cases? _____

Explain your reasoning.

(b) Since the cube in Case B is metal, there will be electrons in it that are free to move around. What, if anything, will happen to those electrons?

Explain your reasoning.

Now the uncharged metal cube in Case B is replaced with an uncharged plastic cube, keeping everything else exactly the same.

(c) Will the force exerted on the positively charged particle by the negatively charged particle be (i) *greater* in Case A, (ii) *greater* in case B, or (iii) *the same* in both cases? _____

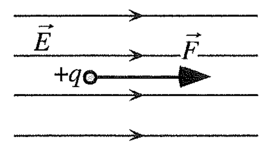
Explain your reasoning.

(d) Since the cube is plastic, there will be no electrons in it that are free to move around, but the molecules can become polarized (i.e., the electrons move closer on average to one end of the molecule and the protons move closer to the other). Will the plastic cube exert a force on the positive charge?

Explain your reasoning.

D1-LMCT33: POSITIVE CHARGE IN A UNIFORM ELECTRIC FIELD—ELECTRIC FORCE

A particle with a charge $+q$ is placed in a uniform electric field.



Identify from choices (i)–(vi) how each change described in (a) to (e) will affect the electric force on the particle.

This change will:

(i) change only the **direction** of the electric force.
(ii) **increase** the magnitude of the electric force.
(iii) **decrease** the magnitude of the electric force.
(iv) **increase** the magnitude and change the **direction** of the electric force.
(v) **decrease** the magnitude and change the **direction** of the electric force.
(vi) **not affect** the electric force.

All of these modifications are changes to the initial situation shown in the diagram.

(a) The charge q on the particle is doubled. _____
Explain your reasoning.

(b) The sign of the charge q on the particle is changed to the opposite sign. _____
Explain your reasoning.

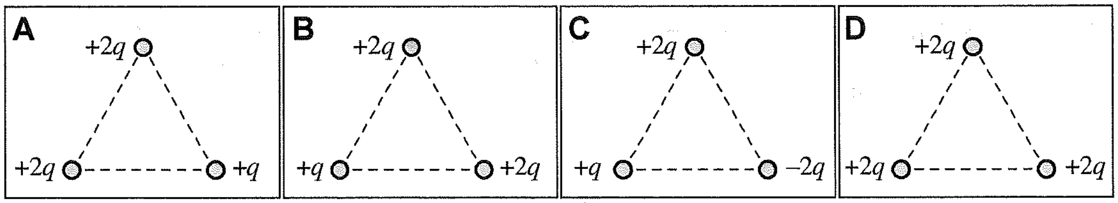
(c) The particle is given a push, causing a leftward initial velocity. _____
Explain your reasoning.

(d) The magnitude of the uniform electric field is halved. _____
Explain your reasoning.

(e) The direction of the uniform electric field is rotated 90° clockwise. _____
Explain your reasoning.

D1-RT36: THREE CHARGED PARTICLES ARRANGED IN A TRIANGLE—FORCE

In each case, three charged particles are fixed in place at the vertices of an equilateral triangle. The triangles are all the same size.



Rank the magnitude of the net electric force on the lower-left particle.

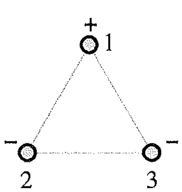
1 Greatest	2	3	4 Least	OR	All the same	All zero	Cannot determine

Explain your reasoning.

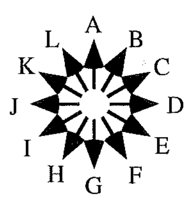
D1-QRT37: FORCE DIRECTION ON THREE CHARGES IN AN EQUILATERAL TRIANGLE—FORCE

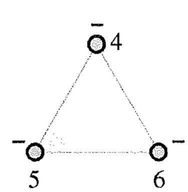
Three charges are fixed at the vertices of each of the equilateral triangles shown below. All charges have the same magnitude. Only charge 1 is positive.

Determine the direction of the net electric force acting on each charge due to the other two charges in the same triangle. Answer by using letters A through L representing directions from the choices below.



	Net Force Direction
Charge 1	
Charge 2	
Charge 3	





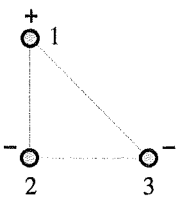
	Net Force Direction
Charge 4	
Charge 5	
Charge 6	

Explain your reasoning.

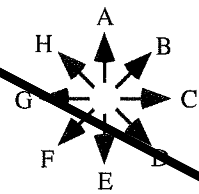
D1-QRT38: FORCE DIRECTION ON THREE CHARGES IN A RIGHT TRIANGLE—FORCE

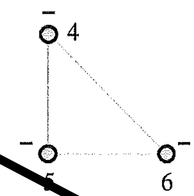
Three charges are fixed at the vertices of each of the right isosceles triangles shown below. All charges have the same magnitude. Only charge 1 is positive.

Determine the direction of the net electric force acting on each charge due to the other two charges in the same triangle. Answer by using letters A through H representing directions from the choices below. If the angle is between two directions, indicate both directions such as AB for a direction between A and B.



	Net Force Direction
Charge 1	
Charge 2	
Charge 3	



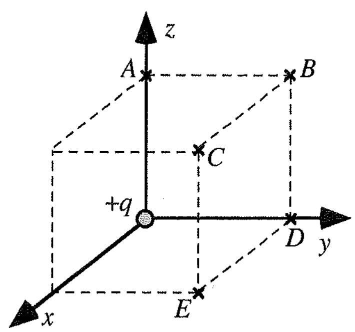


	Net Force Direction
Charge 4	
Charge 5	
Charge 6	

Explain your reasoning.

D1-RT39: NEAR A POINT CHARGE—ELECTRIC FORCE AT THREE-DIMENSIONAL LOCATIONS

There is a positive point charge $+q$ located at (0, 0, 0) in the three-dimensional region below. Within that region are points located on the corners of a cube as shown.



Rank the strength (magnitude) of the electric force on a $+3q$ point charge if it is placed at the labeled points.

☐	☐	☐	☐	☐	OR	☐	☐	☐
1 Greatest	2	3	4	5 Least		All the same	All zero	Cannot determine

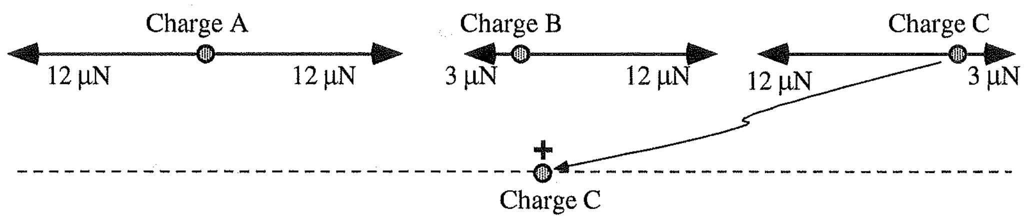
Explain your reasoning.

D1-WBT40: FORCES ON THREE CHARGES ALONG A LINE—CHARGE LOCATION

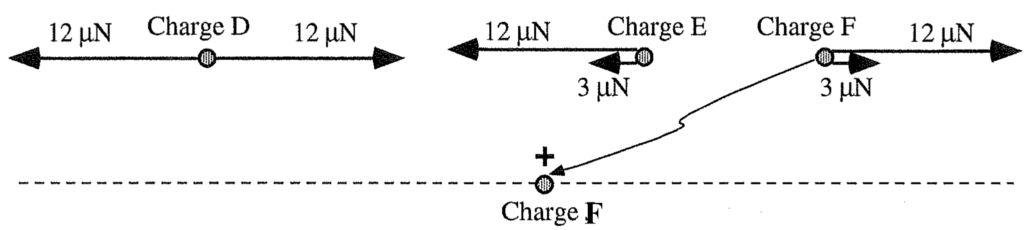
Three charges are fixed in place along a line. All three charges have the same magnitude, but they may have different signs. Shown below are diagrams showing the forces exerted on each charge by the other two charges.

In each case, the sign of one of the charges is shown, as well as its position along a dashed line. **Indicate the signs of the other two charges and their approximate positions on the dashed line.**

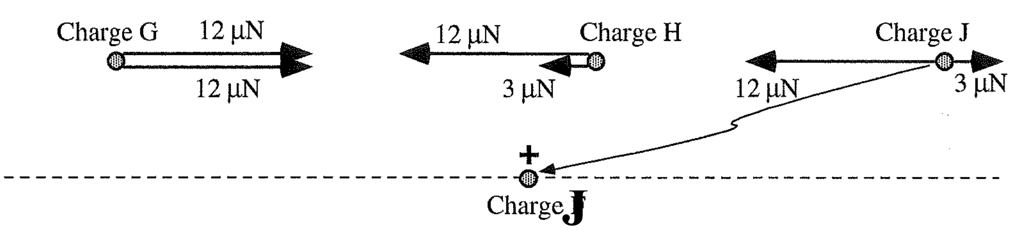
Case 1



Case 2



Case 3

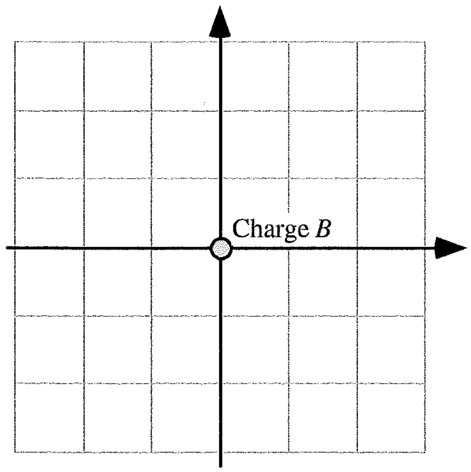


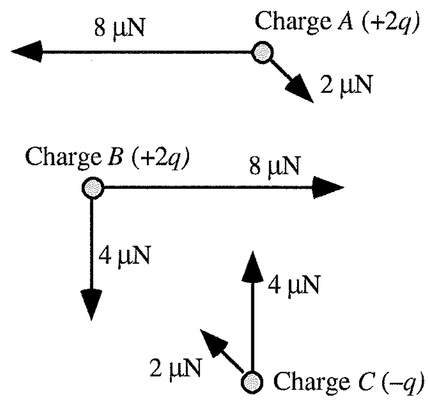
Explain your reasoning.

D1-WBT41: Forces on Three Charges in Two Dimensions—Charge Locations

Three charged particles are fixed to a grid and are exerting electric forces on one another. Particles A and B have a charge $+2q$, and particle C has a charge $-q$. The diagrams at the right, below, show the electric forces exerted on each particle due to the other two particles.

Particle B is shown fixed at the origin of a grid. **On the grid, indicate the positions of particles A and C relative to particle B.**

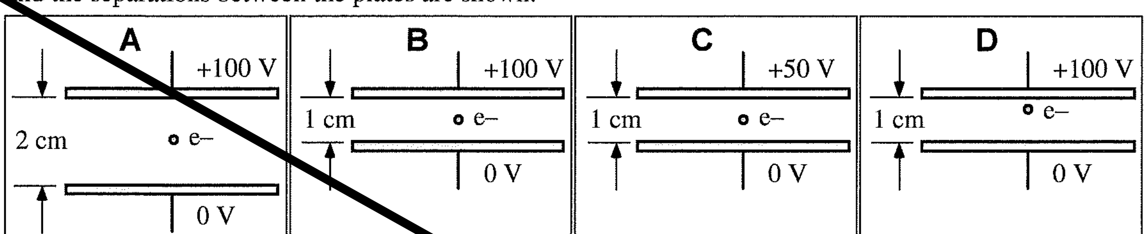




Explain your reasoning.

D1-RT42: Electron Between Two Parallel Charged Plates—Force on the Electron

In each case, an electron is momentarily at rest between two parallel charged plates. The electric potential of each plate and the separations between the plates are shown.



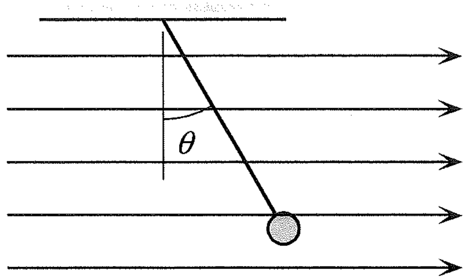
Rank the magnitude of the force exerted on the electron.

☐	☐	☐	☐	OR	☐	☐	☐
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

D1-RT43: SUSPENDED CHARGES IN AN ELECTRIC FIELD—ANGLE

A charged sphere is suspended from a string in a uniform electric field directed horizontally. There is an electric force on the sphere to the right and a gravitational force pointing downward. As a result, the sphere hangs at an angle θ from the vertical. Combinations of sphere mass and electric charge are listed in the chart for four cases, all in the same uniform electric field.



	Mass	Charge
A	3 g	8 nC
B	6 g	4 nC
C	9 g	2 nC
D	6 g	8 nC

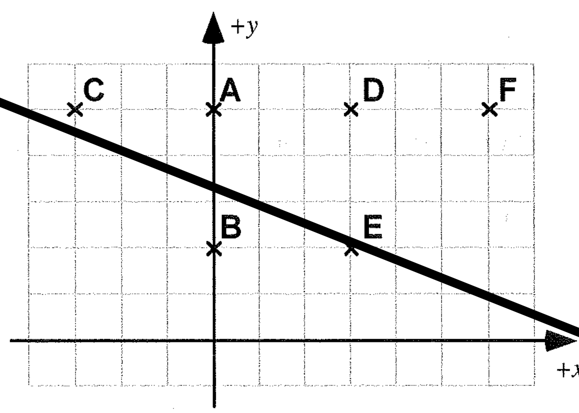
Rank the angle θ that the string forms with the vertical for these different spheres.

1 Greatest	2	3	4 Least	OR	All the same	All zero	Cannot determine

Explain your reasoning.

D1-RT44: UNIFORM ELECTRIC FIELD—ELECTRIC FORCE ON CHARGE

A large region of space has a uniform electric field in the +*x* direction (⇒). At the point (0,0) m, the electric field magnitude is 30 N/C.



	x	*y*
A	0 m	5 m
B	0 m	2 m
C	-3 m	5 m
D	3 m	5 m
E	3 m	2 m
F	6 m	5 m

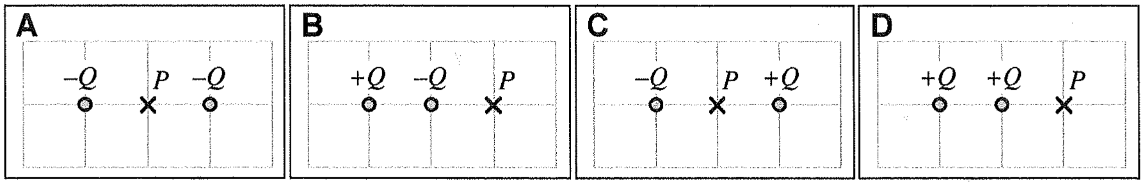
Rank the strength (magnitude) of the electric force on a +5 μC charge when it is placed at rest at each of the labeled points.

1 Greatest	2	3	4	5	6 Least	OR	All the same	All zero	Cannot determine

Explain your reasoning.

D1-RT47: TWO ELECTRIC CHARGES—ELECTRIC FIELD ALONG A LINE

In each figure, two charges are fixed in place on a grid, and a point near those particles is labeled P. All of the charges are the same size, Q, but they can be either positive or negative.



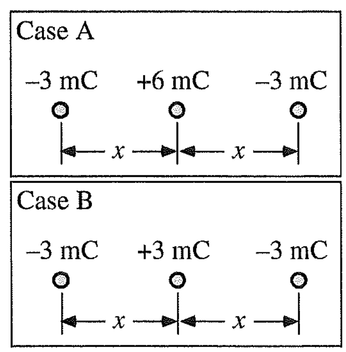
Rank the magnitude of the electric field at point *P*.

1 Greatest	2	3	4 Least	OR	All the same	All zero	Cannot determine

Explain your reasoning.

D1-SCT48: THREE CHARGES IN A LINE—ELECTRIC FIELD

Shown are two cases where three charges are placed in a row. Three students are comparing the electric field that exerts a force on the middle charge in the diagrams.



Adrianna: *"All three charges contribute by the principle of superposition. So the field is going to be greatest in case A since the contributions due to the three charges will be greatest."*

Brandon: *"I think it's a bogus question. The field at that point is undefined because there is a charge there."*

Catalina: *"I don't think that's right. The field that exerts a force on the middle charge is the field due to the other two charges because a charge cannot feel it own field. Since those other two charges don't change, the field acting on the middle charge is the same in both cases."*

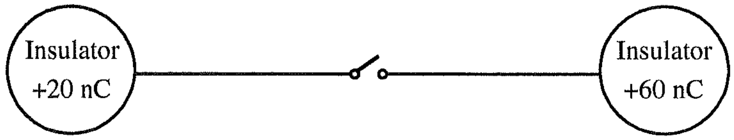
With which of these students do you agree?

Adrianna ______ Brandon _____ Catalina _____ None of them _____

Explain your reasoning.

D1-SCT53: CHARGED INSULATORS CONNECTED WITH A SWITCH—CHARGE

Two solid, insulating spheres are connected by a wire and a switch. The spheres are the same size, but they have different initial charges.



Three students are discussing what would happen if the switch was closed.

Arturo: *"Since the spheres are the same size, charge will move until there is an equal charge of 40 nC on each."*

Beth: *"I agree, but since they are insulators, the charge will move very slowly. Eventually there will be the same charge of 40 nC on each, but it will take a long time, perhaps 5 to 10 minutes.*

Caitlin: *"No, since they are insulators the charge cannot move. It doesn't matter whether the switch is open or closed."*

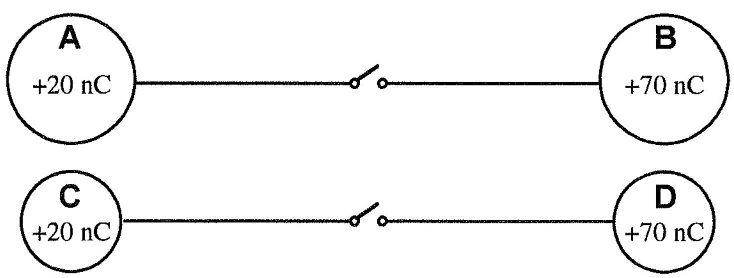
With which of these students do you agree?

Arturo _____ Beth _____ Caitlin _____ None of them _____

Explain your reasoning.

D1-RT54: PAIRS OF CONNECTED CHARGED CONDUCTORS—CHARGE

Two pairs of charged, isolated, conducting spheres are connected with wires and switches. The spheres are very far apart. The larger spheres (A and B) are identical, and the smaller spheres (C and D) are identical. Before the switches are closed, both spheres on the left have a charge of +20 nC, and both spheres on the right have a charge of +70 nC.



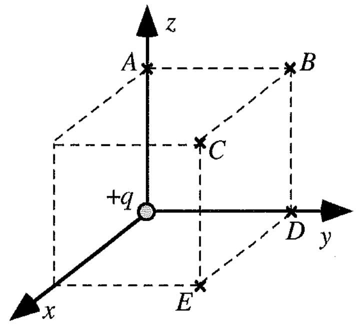
Rank the electric charge on the spheres after the switches are closed.

______	______	______	______	OR	☐	☐	☐
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

D1-RT57: Near a Point Charge—Electric Potential at Three-Dimensional Locations

There is a positive point charge $+q$ located at (0, 0, 0) as shown in the three-dimensional region below. Within that region are points located on the corners of a cube as shown.



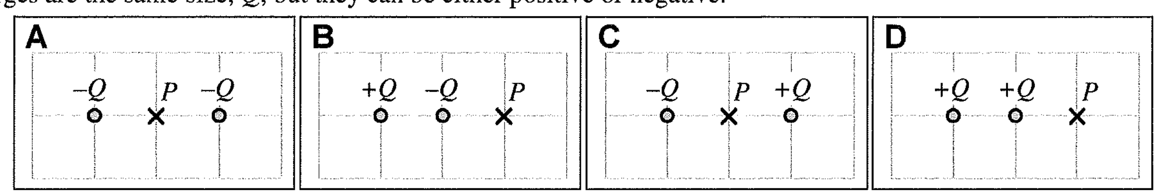
Rank the electric potential at the labeled points.

☐	☐	☐	☐	☐	OR	☐	☐	☐
1 Greatest	2	3	4	5 Least		All the same	All zero	Cannot determine

Explain your reasoning.

D1-RT58: Two Electric Charges—Electric Potential

In each figure, two charges are fixed in place on a grid, and a point near those particles is labeled P. All of the charges are the same size, Q, but they can be either positive or negative.



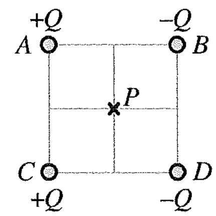
Rank the strength (magnitude) of the electric potential at point *P*.

☐	☐	☐	☐	OR	☐	☐	☐
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

D1-LMCT59: FOUR CHARGES IN TWO DIMENSIONS—FIELD AND POTENTIAL

Four identical point charges are fixed at the same distance from point *P*. The charges are either $+Q$ or $-Q$.



Each action described is made to the situation shown in the diagram (*i.e.*, "Change sign of charge *D*" means that charges *A, C,* and *D* will be positive and charge *B* will be negative).

For each modification:

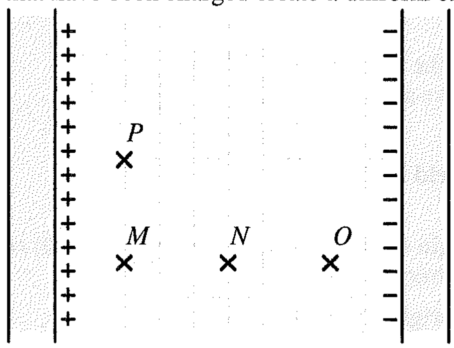
- **Indicate whether the magnitude of the electric field at the origin (i) *increases*, (ii) *decreases*, or (iii) *remains the same.***
- **Indicate whether the electric potential at the origin (i) *increases*, (ii) *decreases*, or (iii) *remains the same.*** (Use the convention that the electric potential is zero far from the charges.)
- **Indicate the direction of the electric field at the origin after the modification.**

	Modification	Electric field	Electric potential	Electric field direction
(a)	Change the sign of charge *A*.			
(b)	Change the sign of charge *B*.			
(c)	Change the sign of charge *C*.			
(d)	Change the sign of charge *D*.			
(e)	Change the signs of charges *B* and *D*.			
(f)	Exchange charges *A* and *B*.			
(g)	Exchange charges *A* and *D*.			

Explain your reasoning.

D1-RT60: Uniform Electric Field—Potential Difference

Two parallel plates that have been charged create a uniform electric field of 30 N/C between the plates.



	From	To
A	M	N
B	N	O
C	P	M
D	P	N
E	P	O
F	N	M

Rank the electrical potential differences of all the different combinations listed between the four points *M* at (2, 0) m; *N* at (5, 0) m; *O* at (8, 0) m; and *P* at (2, 3) m within this region. (Positive values are larger than negative values.)

1 Greatest	2	3	4	5	6 Least	OR	All the same	All zero	Cannot determine

Explain your reasoning.