

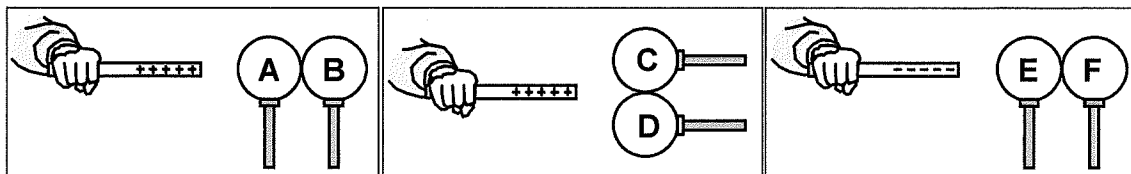
C2-WWT16: Water in Pipe—Speed.....	252
C3 Heat and Temperature	253
C3-SCT01: Fahrenheit Temperature Change—Centigrade Temperature Change.....	253
C3-WWT02: Centigrade Temperature Change— Kelvin Change.....	253
C3-WWT03: Mixing Liquids—Final Temperature.....	253
C3-WWT04: Boiling Water—Temperature.....	254
C3-SCT05: Objects in a Room—Temperature.....	254
C3-CT06: Combining Water, Steam, or Ice—Final Mass and Final Temperature.....	255
C3-CT07: Water and Ice—Temperature.....	256
C3-CT08: Preparing Coffee—Time to Heat.....	256
C3-TT09: Two Glasses of Water—Amount of Heat.....	257
C3-CT10: Combining Two Glasses of Water—Final Temperature.....	257
C3-TT11: Two Pans of Water—Amount of Heat Added.....	258
C3-CT12: Combining Two Glasses of Different Liquids—Final Temperature.....	258
C3-CT13: Thermal Energy in Two Glasses of Water—Temperature.....	259
C3-CRT14: Melting an Ice Cube—Temperature-Time Graph.....	260
C3-CT15: Heating Ice—Final Temperature.....	260
C3-CT16: Mixing Water and/or Ice—Temperature.....	261
C3-CT17: Using a Steel Tape at Different Temperatures—Actual Length.....	261
C3-CT18: Temperature-Time Graph—Properties of Samples.....	262
C3-CT19: Heated Beaker Filled with Glycerin—Overflow.....	262
C3-RT20: Ideal Gas Samples—Temperature I.....	263
C3-RT21: Ideal Gas in Cylinders with Moveable Pistons I—Pressure.....	263
C3-RT22: Gas in Cylinders with Moveable Pistons—Mass.....	264
C3-CT23: Ideal Gases in a Cylinder—Pressure.....	264
C3-CT24: Ideal Gases in Cylinders—Temperature.....	265
C3-WWT25: Ideal Gas in an Insulated Cylinder I—Temperature Change.....	265
C3-WWT26: Ideal Gas in an Insulated Cylinder II—Temperature Change.....	266
C3-RT27: Ideal Gas in Cylinders with Moveable Pistons II—Pressure.....	266
C3-LMCT28: Heavy Moveable Piston in Container with Volume—Pressure.....	267
C3-RT29: Ideal Gases in Cylinders with a Piston—Pressure.....	268
C3-RT30: Ideal Gases in Cylinders with a Piston—Number of Moles.....	268
C3-RT31: Ideal Gases in Cylinders with a Piston—Temperature.....	269
C3-RT32: Pressure-Volume Graph I—Temperature in Different States.....	269
C3-RT33: Pressure-Volume Graph II—Temperature in Different States.....	270
C3-RT34: Thermodynamic Ideal Gas Processes—Final Temperature.....	270
C3-CRT35: Pressure-Volume Graph—Pressure, Volume, and Temperature Bar Charts.....	271
C3-CT36: Pressure-Volume Graphs for Expanding Gas—Work Done.....	271
C3-WWT37: Pressure-Volume Graph for Two Processes—Change in Temperature.....	272
C3-RT38: Pressure-Volume Graphs for Various Processes—Work Done by Gas.....	272
C3-CT39: Isothermal and Adiabatic Ideal Gas Processes—Work, Heat, and Temperature.....	273
C3-CT40: Pressure-Volume Graph for Processes—Work Done.....	273
C3-CT41: Pressure-Volume Graph for Various Processes—Work.....	274
C3-LMCT42: Carnot Heat Engine I—Efficiency.....	275
C3-WWT43: Carnot Engine II—Efficiency.....	276
C3-SCT44: Carnot Engine III—Efficiency.....	276
D1 Electrostatics	277
D1-RT01: Electroscope near a Charged Rod—Electroscope Net Charge.....	277
D1-RT02: Transfer of Charge in Conductors—Charge on Left Conductor.....	277
D1-RT03: Induced Charges near a Charged Rod—Net Charge.....	278
D1-WWT04: Charged Insulator and a Grounded Conductor—Induced Charge.....	278
D1-QRT05: Three Conducting Spheres—Charge.....	279
D1-WWT06: Uncharged Metal Sphere near a Charged Rod—Charge Distribution.....	280
D1-SCT07: Charged Rod and Electroscope—Deflection.....	280
D1-QRT08: Charged Rod near Electroscope—Charge.....	281

D1-QRT09: Two Charges—Force on Each.....	282
D1-WWT10: Two Negative Charges—Force	282
D1-WWT11: Two Negatively Charged Particles—Force	283
D1-RT12: Two Electric Charges—Electric Force.....	283
D1-RT13: Pairs of Point Charges—Attractive and Repulsive Force.....	284
D1-RT14: Two Charged Particles—Force	284
D1-TT15: Two Charged Objects—Force	285
D1-RT16: Two and Three Charges in a Line—Force	285
D1-RT17: Charged Particles in a Plane—Force	286
D1-RT18: Three Linear Electric Charges—Electric Force	286
D1-QRT19: Two Unequal Charges—Force	287
D1-QRT20: Three Charges in a Line I—Force	288
D1-QRT21: Three Charges in a Line II—Force.....	289
D1-QRT22: Three Charges in a Line III—Force	290
D1-BCT23: Three Charges in a Line IV—Force	291
D1-TT24: Neutral Metal Sphere near a Positive Point Charge—Force	292
D1-SCT25: Uncharged Metal Sphere near a Positive Point Charge—Force.....	292
D1-WWT26: Neutral Metal Sphere near a Positive Point Charge—Force	293
D1-RT27: Neutral Metal Sphere near a Point Charge—Force.....	293
D1-LMCT28: Neutral Metal Sphere near a Positive Point Charge—Force	294
D1-CT29: Conducting Cube between Point Charges—Net Force	295
D1-QRT30: Cubes between Point Charges—Force Exerted by One Charge on the Other	295
D1-RT31: Two Charged Particles—Acceleration.....	296
D1-WWT32: Electron in a Uniform Electric Field—Velocity.....	296
D1-LMCT33: Positive Charge in a Uniform Electric Field—Electric Force	297
D1-SCT34: Electron in a Uniform Electric Field—Electric Force.....	298
D1-SCT35: Two Negatively Charged Particles—Acceleration	298
D1-RT36: Three Charged Particles arranged in a Triangle—Force	299
D1-QRT37: Force Direction on Three Charges in an Equilateral Triangle—Force.....	299
D1-QRT38: Force Direction on Three Charges in a Right Triangle—Force	300
D1-RT39: Near a Point Charge—Electric Force at Three-Dimensional Locations.....	300
D1-WBT40: Forces on Three Charges Along a Line—Charge Location.....	301
D1-WBT41: Forces on Three Charges in Two Dimensions—Charge Locations.....	302
D1-RT42: Electron Between Two Parallel Charged Plates—Force on the Electron.....	302
D1-RT43: Suspended Charges in an Electric Field—Angle	303
D1-RT44: Uniform Electric Field—Electric Force on Charge.....	303
D1-RT45: Uniform Electric Field—Electric Force at Three-Dimensional Locations.....	304
D1-BCT46: Point Charge—Electric Field.....	304
D1-RT47: Two Electric Charges—Electric Field along a Line.....	305
D1-SCT48: Three Charges in a Line—Electric Field.....	305
D1-RT49: Four Point Charges in Two Dimensions—Electric Field.....	306
D1-RT50: Six Charges in Three Dimensions—Electric Field.....	306
D1-TT51: Potential near Two Charges—Electric Field	307
D1-CT52: Potential near Charges—Electric Field	307
D1-SCT53: Charged Insulators connected with a Switch—Charge.....	308
D1-RT54: Pairs of Connected Charged Conductors—Charge	308
D1-RT55: Four Charges in Two Dimensions—Electric Potential	309
D1-RT56: Points near a Pair of Equal Opposite Charges—Electric Potential	309
D1-RT57: Near a Point Charge—Electric Potential at Three-Dimensional Locations.....	310
D1-RT58: Two Electric Charges—Electric Potential.....	310
D1-LMCT59: Four Charges in Two Dimensions—Field and Potential.....	311
D1-RT60: Uniform Electric Field—Potential Difference	312
D2 Circuits	313
D2-RT01: Carbon Resistors—Resistance	313
D2-WWT02: Batteries and Light Bulbs—Bulb Brightness	313

TIPERS

D1-RT03: INDUCED CHARGES NEAR A CHARGED ROD—NET CHARGE

A charged rod is moved to the same distance from a pair of uncharged metal spheres as shown. The spheres in each pair are initially in contact, but they are then separated while the rod is still in place. Then the rod is removed.



Rank the net charge on each sphere from most positive to most negative after the spheres have been separated and the charged rod removed.

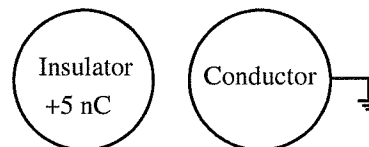
1	2	3	4	5	6	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Greatest					Least		All the same	All zero	Cannot determine

Explain your reasoning.

D1-WWT04: CHARGED INSULATOR AND A GROUNDED CONDUCTOR—INDUCED CHARGE

A charged insulating sphere and a grounded conducting sphere are initially far apart. The charged insulator is then moved near the grounded conductor as shown. A student makes the following statement:

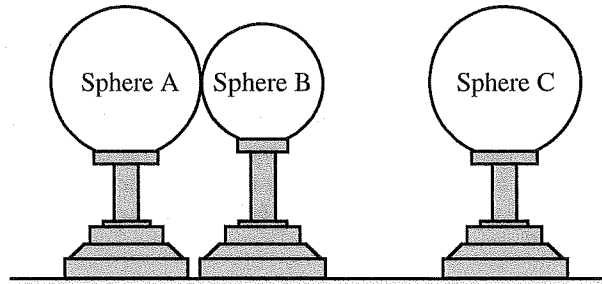
“When the charged insulator is brought close to the grounded conductor, it will cause the negative charges in the conductor to move to the side closest to the insulator. If the charged insulator is taken away, the conductor will be left with a negative charge evenly distributed over its surface.”



What, if anything, is wrong with this statement? If something is wrong, explain the error and how to correct it. If the statement is valid, explain why.

D1-QRT05: THREE CONDUCTING SPHERES—CHARGE

Two conducting spheres rest on insulating stands. Sphere B is smaller than Sphere A. Both spheres are initially uncharged and they are touching. A third conducting sphere, C, has a positive charge. It is brought close to (but not touching) Sphere B as shown.



(a) Is the net charge on Sphere A at this time (i) *positive*, (ii) *negative*, or (iii) *zero*? _____

Explain your reasoning.

(b) Is the net charge on Sphere B at this time (i) *positive*, (ii) *negative*, or (iii) *zero*? _____

Explain your reasoning.

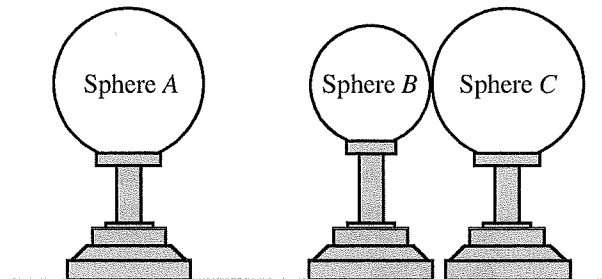
(c) Is the magnitude of the net charge on Sphere A (i) *greater than*, (ii) *less than*, or (iii) *equal to* the magnitude of the net charge on Sphere B? _____

Explain your reasoning.

Sphere B is now moved to the right so that it touches Sphere C. As a result of this move:

(d) Does the magnitude of the net charge on Sphere A (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.



(e) Does the magnitude of the net charge on Sphere C (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

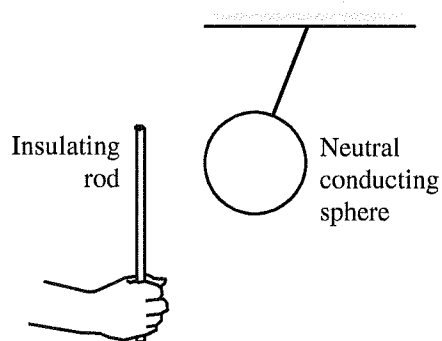
TIPERS

D1-WWT06: UNCHARGED METAL SPHERE NEAR A CHARGED ROD—CHARGE DISTRIBUTION

A student observes a demonstration involving an interaction between a neutral metallic sphere suspended from a string and a negatively charged insulating rod. The student makes the following statement:

“As the negatively charged rod nears the sphere, it causes the electrons in the sphere to move away from the rod. The side of the sphere nearest to the rod becomes positively charged while the other side becomes negatively charged. So the sphere will be attracted toward the rod. If they touch, the sphere will swing back since they will both become neutral.”

What, if anything, is wrong with this statement? If something is wrong, explain the error and how to correct it. If the statement is valid, explain why.



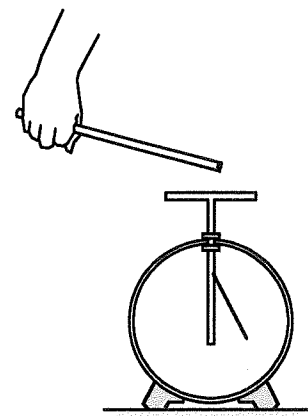
D1-SCT07: CHARGED ROD AND ELECTROSCOPE—DEFLECTION

A positively charged rod is brought near an electroscope. Even though the rod does not touch the electroscope, the leaf of the electroscope deflects. Below, three students discuss this demonstration.

Amadeo: *“There are positive charges that jump from the rod to the plate of the electroscope. Since the electroscope is now charged, the leaf moves out.”*

Barun: *“Charges don’t have to move from the rod to the plate to deflect. When the rod comes close, electrons in the electroscope move toward the plate. This leaves the bottom of the electroscope positively charged, and the leaf lifts.”*

Carmen: *“Positive charges are fixed in place. When the rod is brought close to the electroscope plate, the electrons in the plate are attracted and jump to the rod. This leaves the electroscope positively charged, and the leaf lifts.”*



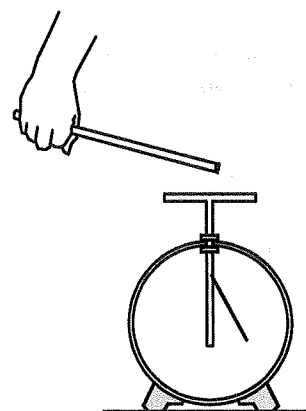
With which of these students do you agree?

Amadeo _____ Barun _____ Carmen _____ None of them _____

Explain your reasoning.

D1-QRT08: CHARGED ROD NEAR ELECTROSCOPE—CHARGE

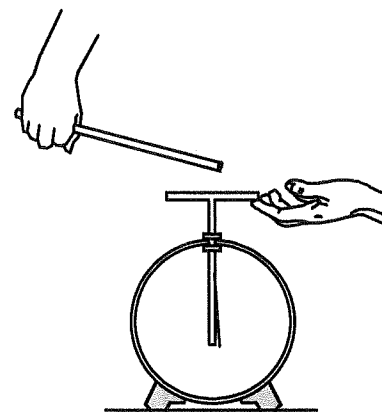
A student first holds a positively charged rod near the top plate of an electroscope without touching it. The electroscope foil deflects. The electroscope was initially uncharged.



(a) Is the electroscope now (i) *positively charged*, (ii) *negatively charged*, or (iii) *neutral*. _____

Explain your reasoning.

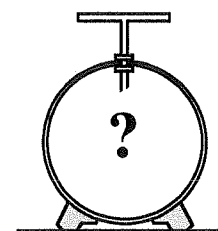
She then touches the electroscope plate while keeping the positively charged rod near the plate. The electroscope foil falls back to its undeflected position.



(b) Is the electroscope (i) *positively charged*, (ii) *negatively charged*, or (iii) *neutral*. _____

Explain your reasoning.

While holding the positively charged rod stationary, she removes her hand which is touching the electroscope. Finally, she removes the charged rod.



(c) Is the electroscope (i) *positively charged*, (ii) *negatively charged*, or (iii) *uncharged*. _____

Explain your reasoning.

(d) Will the electroscope foil be (i) *deflected* or (ii) *undeflected*? _____

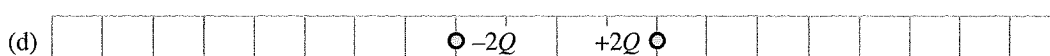
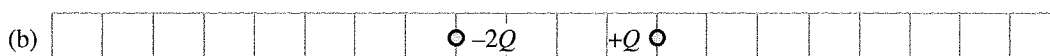
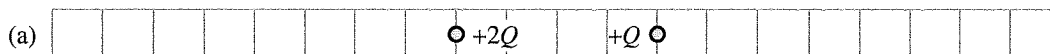
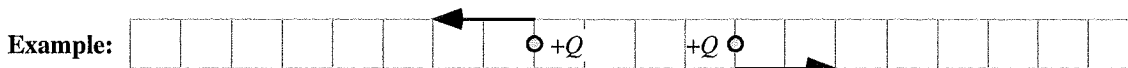
Explain your reasoning.

TIPERS

D1-QRT09: TWO CHARGES—FORCE ON EACH

In each case shown below, two charges are fixed in place and are exerting forces on each other.

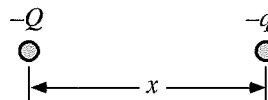
For each case, draw a vector of appropriate length and direction representing the electric force acting on each charge due to the other charge. Draw the vector representing the force *with the length proportional to the magnitude* on the left charge *above* that charge; and draw the vector representing the force *with the length proportional to the magnitude* on the right charge *below* that charge (see the example). For each diagram, use the same scale as the example.



Explain your reasoning.

D1-WWT10: TWO NEGATIVE CHARGES—FORCE

Two negatively charged particles are separated by a distance x . The particle on the left has a charge $-Q$ which is three times the charge $-q$ of the particle on the right.



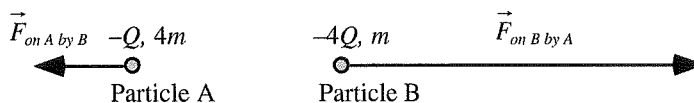
A student makes the following statement:

“Since $F = kQq/x^2$ and Q and q are both negative, the force on Q will be positive. Therefore, the force on Q points to the right.”

What, if anything, is wrong with this statement? If something is wrong, explain the error and how to correct it. If the statement is valid, explain why.

D1-WWT11: TWO NEGATIVELY CHARGED PARTICLES—FORCE

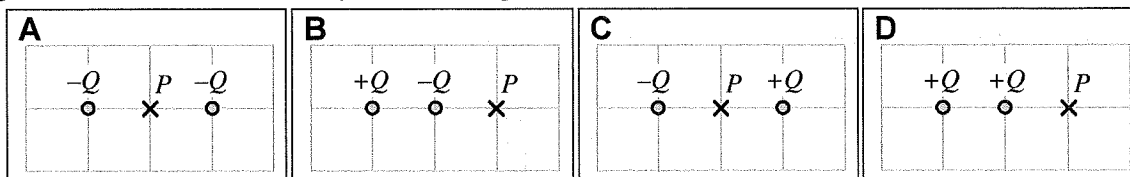
A student's diagram for the electric forces acting on two negatively charged ($-Q$ and $-4Q$) particles is shown. Particle A has four times the mass of particle B.



What, if anything, is wrong with this diagram? If something is wrong, explain the error and how to correct it. If the diagram is valid, explain why.

D1-RT12: TWO ELECTRIC CHARGES—ELECTRIC FORCE

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 force on a charge $+q$ that is placed at point P .

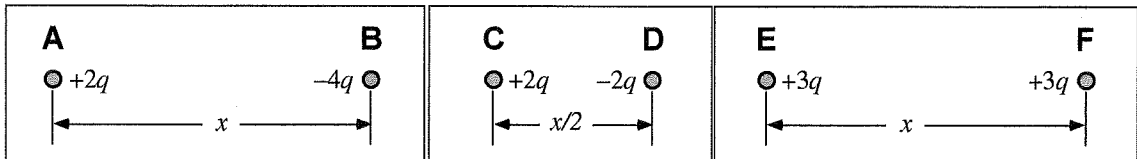
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1	2	3	4		All	All	Cannot
Greatest			Least		the same	zero	determine

Explain your reasoning.

TIPERS

D1-RT13: PAIRS OF POINT CHARGES—ATTRACTIVE AND REPULSIVE FORCE

The following diagrams show three separate pairs of point charges.



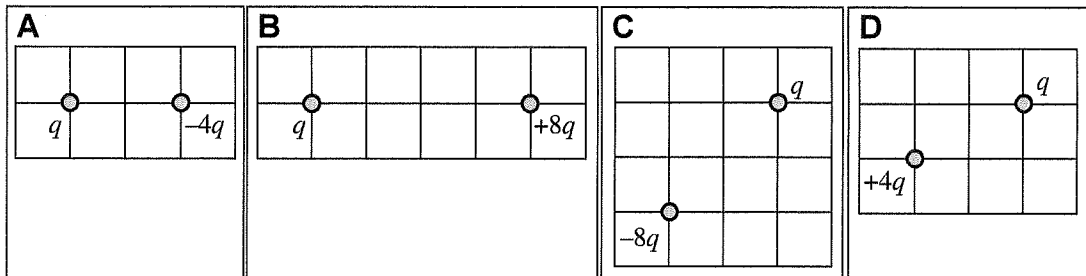
Rank the force on each point charge from most attractive to most repulsive.

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

Explain your reasoning.

D1-RT14: TWO CHARGED PARTICLES—FORCE

In each case, small charged particles are fixed on grids having the same spacing. Each charge q is identical, and all other charges have a magnitude that is an integer multiple of q .



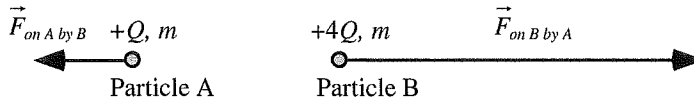
Rank the magnitude of the electric force on the charge labeled q due to the other charge.

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

Explain your reasoning.

D1-TT15: TWO CHARGED PARTICLES—FORCE

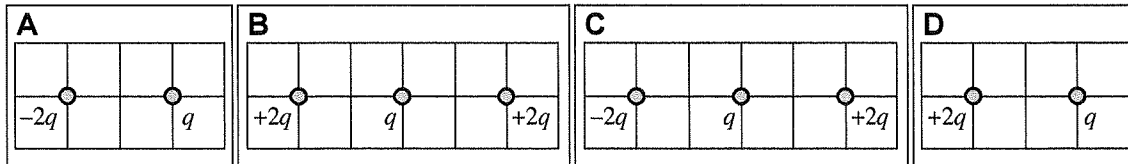
Shown below is a student's drawing of the electric forces acting on Particle A (with charge $+Q$ and mass m) and Particle B (with charge $+4Q$ and mass m).



There is something wrong with this diagram. Explain what is wrong and how to correct it.

D1-RT16: TWO AND THREE CHARGES IN A LINE—FORCE

In each case, small charged particles are fixed on grids having the same spacing. Each charge q is identical, and all other charges have a magnitude that is an integer multiple of q .



Rank the magnitude of the electric force on the charge labeled q due to the other charges.

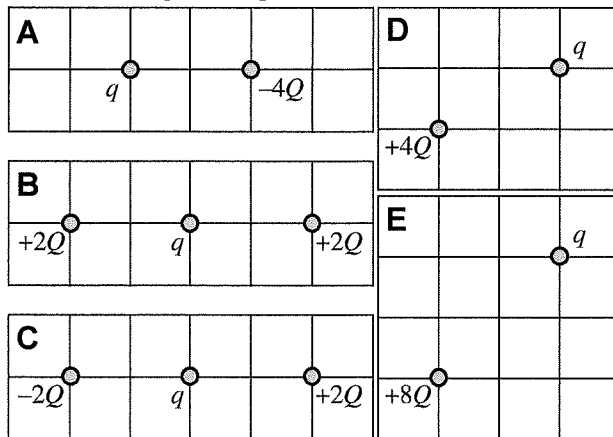
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	OR	<input type="text"/>	<input type="text"/>	<input type="text"/>
1	2	3	4		All the same	All zero	Cannot determine
Greatest							Least

Explain your reasoning.

TIPERS

D1-RT17: CHARGED PARTICLES IN A PLANE—FORCE

In each case, small charged particles are fixed on grids having the same spacing. Each charge q is identical, and all other charges have a magnitude that is an integer multiple of Q .



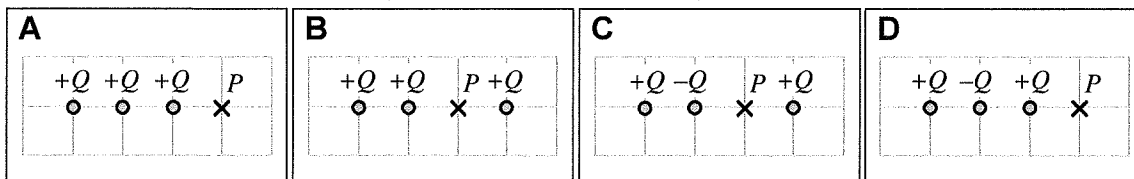
Rank the magnitude of the net electric force on the charge labeled q due to the other charges.

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

Explain your reasoning.

D1-RT18: THREE LINEAR ELECTRIC CHARGES—ELECTRIC FORCE

In each figure, three 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 net electric force on a charge $+q$ that is placed at point P .

<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	OR	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>
1	2	3	4		All	All	Cannot
Greatest			Least		the same	zero	determine

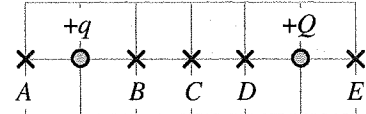
Explain your reasoning.

D1-QRT19: TWO UNEQUAL CHARGES—FORCE

Shown below are two charged particles that are fixed in place. The magnitude of the charge Q is greater than the magnitude of the charge q . A third charge is now placed at one of the points A – E . The net force on this charge due to q and Q is zero.

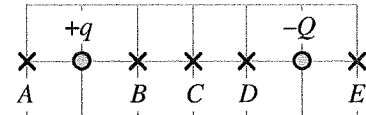
(a) Both q and Q are positive.

At which point A – E is it possible that the third charge was placed? _____
 Explain your reasoning.



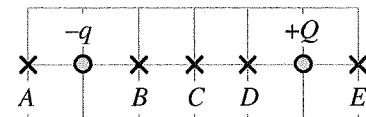
(b) Charge q is positive and charge Q is negative.

At which point A – E is it possible that the third charge was placed? _____
 Explain your reasoning.



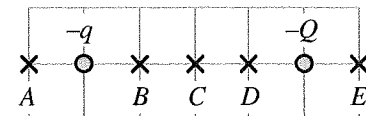
(c) Charge q is negative and charge Q is positive.

At which point A – E is it possible that the third charge was placed? _____
 Explain your reasoning.



(d) Both q and Q are negative.

At which point A – E is it possible that the third charge was placed? _____
 Explain your reasoning.



TIPERs

D1-QRT20: THREE CHARGES IN A LINE I—FORCE

Three charged particles, *A*, *B*, and *C*, are fixed in place in a line. Charge *C* is twice as far from charge *B* as charge *A* is. All charges are the same magnitude.

In the chart to the left below, use arrows (\leftarrow or \rightarrow) to indicate the direction of the net force on charge *C* due to charges *A* and *B*. If the force is zero, state that explicitly.

In the chart on the right below, use arrows (\leftarrow or \rightarrow) to indicate the direction of the net force on charge *B* due to charges *A* and *C*. If the force is zero, state that explicitly.

$\Sigma \vec{F}$ on charge <i>C</i>				$\Sigma \vec{F}$ on charge <i>B</i>			
A ⊙ +	B ⊙ +	C ⊙ +	Direction:	A ⊙ +	B ⊙ +	C ⊙ +	Direction:
A ⊙ +	B ⊙ +	C ⊙ -	Direction:	A ⊙ +	B ⊙ +	C ⊙ -	Direction:
A ⊙ +	B ⊙ -	C ⊙ +	Direction:	A ⊙ +	B ⊙ -	C ⊙ +	Direction:
A ⊙ +	B ⊙ -	C ⊙ -	Direction:	A ⊙ +	B ⊙ -	C ⊙ -	Direction:
A ⊙ -	B ⊙ +	C ⊙ +	Direction:	A ⊙ -	B ⊙ +	C ⊙ +	Direction:
A ⊙ -	B ⊙ +	C ⊙ -	Direction:	A ⊙ -	B ⊙ +	C ⊙ -	Direction:
A ⊙ -	B ⊙ -	C ⊙ +	Direction:	A ⊙ -	B ⊙ -	C ⊙ +	Direction:
A ⊙ -	B ⊙ -	C ⊙ -	Direction:	A ⊙ -	B ⊙ -	C ⊙ -	Direction:

Explain your reasoning.

D1-QRT21: THREE CHARGES IN A LINE II—FORCE

Three charged particles, A , B , and C , are fixed in place in a line. Charge C is twice as far from charge B as charge A is. All charges have different magnitudes.



For each of the following combinations of charge signs, determine whether it is possible for the net electric force on each charge due to the other two charges to be zero.

			$\Sigma \vec{F}$ on charge A	$\Sigma \vec{F}$ on charge B	$\Sigma \vec{F}$ on charge C
A ⊙ +	B ⊙ +	C ⊙ +	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>
A ⊙ +	B ⊙ +	C ⊙ -	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>
A ⊙ +	B ⊙ -	C ⊙ +	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>
A ⊙ +	B ⊙ -	C ⊙ -	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>
A ⊙ -	B ⊙ +	C ⊙ +	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>
A ⊙ -	B ⊙ +	C ⊙ -	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>
A ⊙ -	B ⊙ -	C ⊙ +	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>
A ⊙ -	B ⊙ -	C ⊙ -	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>	Must be nonzero <input type="checkbox"/> Possibly zero <input type="checkbox"/>

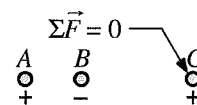
Explain your reasoning.

TIPERS

D1-QRT22: THREE CHARGES IN A LINE III—FORCE

Three charged particles are fixed in place in a line. Charge C is twice as far from charge B as charge A is. It is known that there is no net force on charge C due to charges A and B .

Indicate whether each of the following statements is *true*, *false*, or *cannot be determined*.

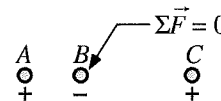


Statement	True	False	Cannot be determined
(a) Charge A has a greater magnitude than charge C .			
(b) Charge A has a greater magnitude than charge B .			
(c) Charge C has a greater magnitude than charge B .			
(d) Charge A has the same magnitude as charge C .			
(e) Charge A has the same magnitude as charge B .			
(f) Charge C has the same magnitude as charge B .			

Explain your reasoning.

Three charged particles, A , B , and C , are fixed in place in a line. Charge C is twice as far from charge B as charge A is. It is known that there is no net force on charge B due to charges A and C .

Indicate whether each of the following statements is *true*, *false*, or *cannot be determined*.



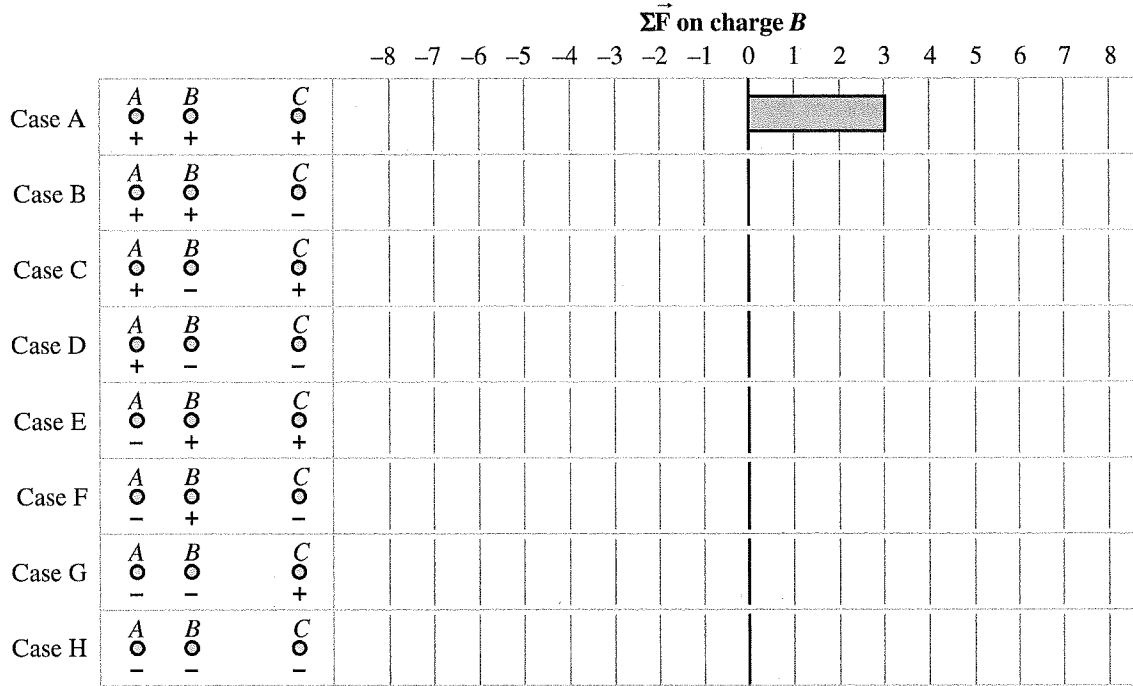
Statement	True	False	Cannot be determined
(g) Charge A has a greater magnitude than charge C .			
(h) Charge A has a greater magnitude than charge B .			
(i) Charge C has a greater magnitude than charge B .			
(j) Charge A has the same magnitude as charge C .			
(k) Charge A has the same magnitude as charge B .			
(l) Charge C has the same magnitude as charge B .			

Explain your reasoning.

D1-BCT23: THREE CHARGES IN A LINE IV—FORCE

Three charged particles, *A*, *B*, and *C*, are fixed in place in a line. Charge *C* is twice as far from charge *B* as charge *A* is. All charges have the same magnitude.

Construct a bar chart for the net force on charge *B* due to charges *A* and *C*. Use positive values for net forces directed to the right and negative values for net forces directed to the left. If the force is zero, state that explicitly.



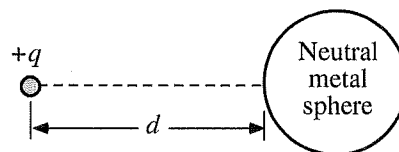
Explain your reasoning.

TIPERs

D1-TT24: NEUTRAL METAL SPHERE NEAR A POSITIVE POINT CHARGE—FORCE

A positive point charge is placed a distance d away from a neutral solid metal sphere.

A student makes the following statement about the electric force between the neutral metal sphere and the point charge:



“There is an attraction between the point charge and the sphere. Since the sphere is a conductor, the external positive point charge pulls electrons in the sphere toward it. This leaves positive charges on the other side of the sphere, since the sphere is still neutral. The force between the point charge and the sphere is just the attraction between the negative charges on the left end of the sphere and the point charge.”

There is at least one problem with this student’s contention. Identify any problem(s) and explain how to correct it/them.

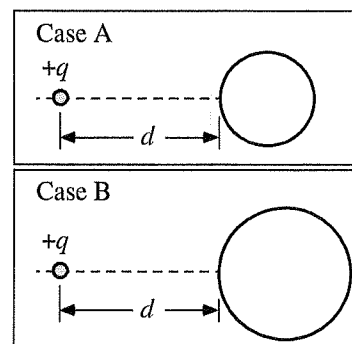
D1-SCT25: UNCHARGED METAL SPHERE NEAR A POSITIVE POINT CHARGE—FORCE

In each case shown, a point charge $+q$ is a distance d from the closest point of an uncharged metal sphere. The sphere in Case B has a larger diameter than the sphere in case A. Three students are comparing the two cases:

Aaron: *“I don’t think there would be any electric forces in either case. Since the sphere has no net charge, there is no attraction or repulsion.”*

Bae: *“The forces on the point charges are equal in the two cases. There is an attraction because the point charge will pull the electrons in the sphere toward it. But the distance between the point charge and the electrons is the same in both cases, so the force of attraction is the same.”*

Carlota: *“When the electrons are pulled toward the point charge, they leave a pool of positive charges on the other side of the sphere. These positive charges repel the point charge, and this balances the attraction of the electron. The sphere overall is still uncharged, so there is as much positive charge as negative charge, and there is no net force between the objects.”*



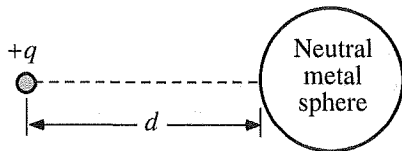
With which of these students do you agree?

Aaron _____ Bae _____ Carlota _____ None of them _____

Explain your reasoning.

D1-WWT26: NEUTRAL METAL SPHERE NEAR A POSITIVE POINT CHARGE—FORCE

A positive point charge is placed a distance d away from a neutral metal sphere.



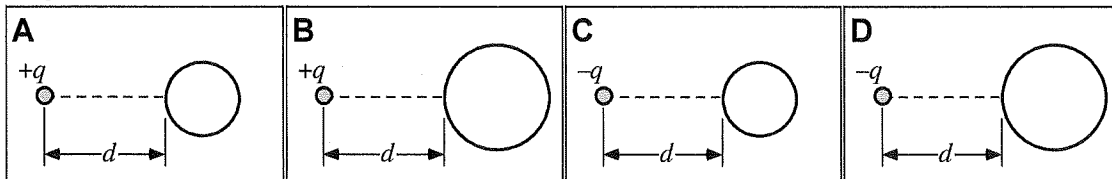
A student makes the following statement:

“The electric force is zero. Coulomb’s law states that the electric force between two objects is proportional to the product of the charges. Since the charge of the sphere is zero, and zero times anything gives zero, the force between the point charge and the sphere is zero.”

What, if anything, is wrong with this statement? If something is wrong, explain the error and how to correct it. If the statement is valid, explain why.

D1-RT27: NEUTRAL METAL SPHERE NEAR A POINT CHARGE—FORCE

A point charge is placed a distance d away from a neutral metal sphere. The diameters of the spheres in Cases A and C are the same and smaller than the equal diameters in Cases B and D. The point charge is positive for Cases A and B, and negative for Cases C and D.



Rank the magnitude of the force exerted on the point charge by the sphere.

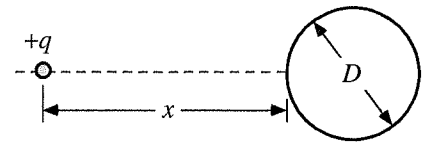
				OR			
1	2	3	4		All	All	Cannot
Greatest			Least		the same	zero	determine

Explain your reasoning.

TIPERS

D1-LMCT28: NEUTRAL METAL SPHERE NEAR A POSITIVE POINT CHARGE—FORCE

A positive point charge is placed a distance x away from the closest surface of a neutral metal sphere that has a diameter D .



(a) For each change listed, state whether the magnitude of the force exerted on the point charge by the sphere *increases, decreases, or remains the same*. (Assume that all of the other given variables remain the same for each change given.)

Change	Effect on the force exerted on the particle			
	No force	Increases	Decreases	Remains the Same
(a) Increase the distance x .				
(b) Increase D , keeping the charge a distance x away.				
(c) Increase the charge of the particle.				
(d) Make the charge of the particle $-q$.				
(e) Add negative charge to the sphere.				

Explain your reasoning.

(b) For each change listed, state whether the magnitude of the force exerted on the sphere by the point charge *increases, decreases, or remains the same*. (Assume that all of the other given variables remain the same for each change given.)

Change	Effect on the force exerted on the sphere			
	No force	Increases	Decreases	Remains the Same
(f) Increase the distance x .				
(g) Increase D , keeping the charge a distance x away.				
(h) Increase the charge of the particle.				
(i) Make the charge of the particle $-q$.				
(j) Add negative charge to the sphere.				

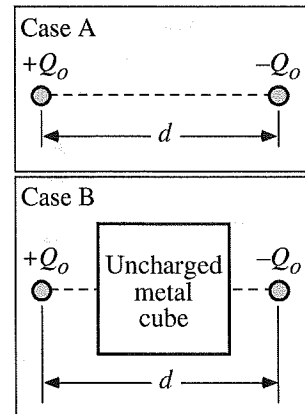
Explain your reasoning.

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**

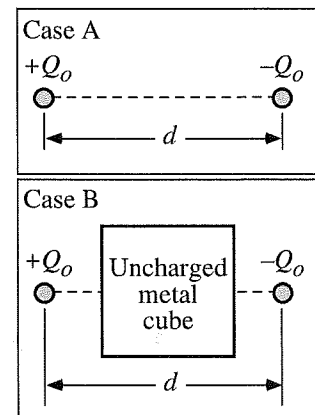
In both cases, two equal and opposite charges are fixed in place a distance d apart. The cases are identical, except that in Case B an uncharged metal cube is placed between the two charges.

(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.

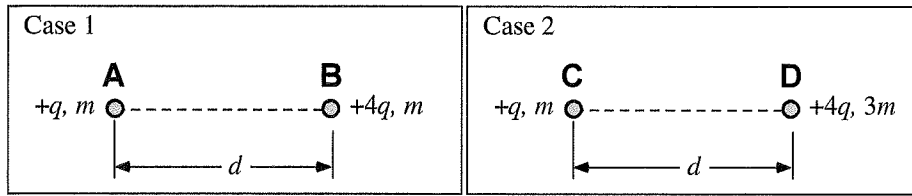
(d) Since the cube is plastic, there will be no electrons in it that are free to move around, but the molecules can become polarized (i.e., the electrons move closer on average to one end of the molecule and the protons move closer to the other). Will the plastic cube exert a force on the positive charge?

Explain your reasoning.

TIPERS

D1-RT31: TWO CHARGED PARTICLES—ACCELERATION

In each case shown, a particle of charge $+q$ is placed a distance d from a particle of charge $+4q$. The particles are then released simultaneously. The masses of the particles are indicated in the diagram.



Rank the magnitude of the acceleration of each particle just after it is released.

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

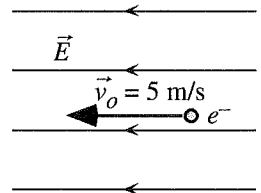
Explain your reasoning.

D1-WWT32: ELECTRON IN A UNIFORM ELECTRIC FIELD—VELOCITY

An electron is placed in a uniform electric field with an initial velocity of 5 m/s as shown. A student makes the following statement:

“The electron will continue to move in the same direction at a constant velocity because it is moving in the same direction as the electric force on it; since the electric field is constant, the force on the electron is constant.”

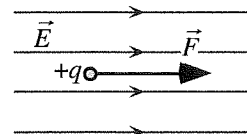
What, if anything, is wrong with this statement? If something is wrong, explain the error and how to correct it. If the statement is valid, explain why.



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. _____

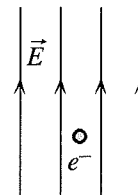
Explain your reasoning.

TIPERS

D1-SCT34: ELECTRON IN A UNIFORM ELECTRIC FIELD—ELECTRIC FORCE

Consider the following statements about the motion of an electron placed at rest in a uniform electric field as shown and then released:

- Anna: "Since the electron is negative, it will move downward. Since the field is uniform, it will move at a constant velocity proportional to the strength of the electric field."
- Brooke: "The electron will accelerate upward because particles move in the direction of the electric field, which points upward."
- Chico: "The electron will move downward because it is a negative particle. The force acting on it will be opposite the direction of the electric field. It will move with a constant acceleration."



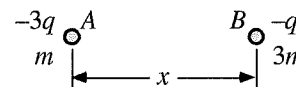
With which of these students do you agree?

Anna _____ Brooke _____ Chico _____ None of them _____

Explain your reasoning.

D1-SCT35: TWO NEGATIVELY CHARGED PARTICLES—ACCELERATION

Two negatively charged particles labeled A and B are separated by a distance x . The particles have different charges and masses as shown.



Three students are discussing what will happen just after the particles are released.

- Antonio: "The magnitude of the force that A exerts on B will be the same as the magnitude of the force that B exerts on A. Since A has less mass, it will have a larger acceleration."
- Brenda: "The magnitude of the force on A by B is greater than the magnitude of the force on B by A since B has more mass. So A will have the largest acceleration."
- Cho: "A has more charge but it has less mass. The larger mass of B is exactly compensated for by the larger charge of A. The acceleration of both will be the same."

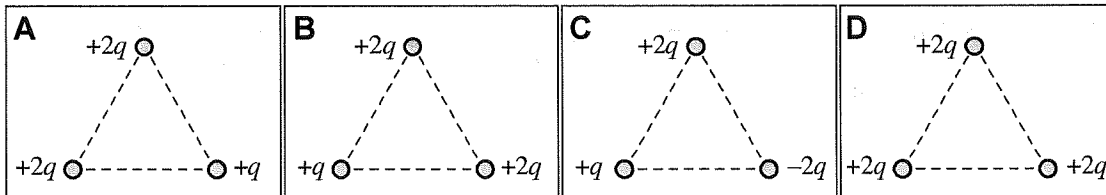
With which of these students do you agree?

Antonio _____ Brenda _____ Cho _____ None of them _____

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	2	3	4
Greatest			Least

OR

All the same

All zero

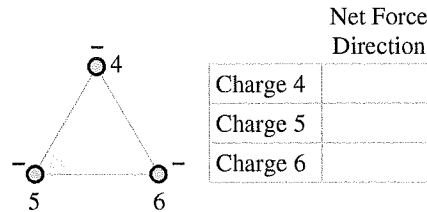
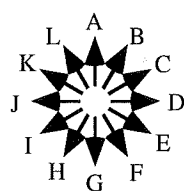
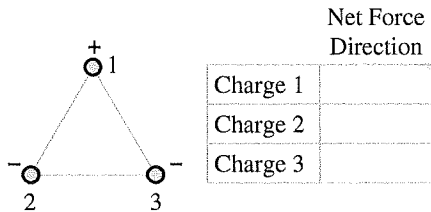
Cannot determine

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.



Explain your reasoning.

TIPERS

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.

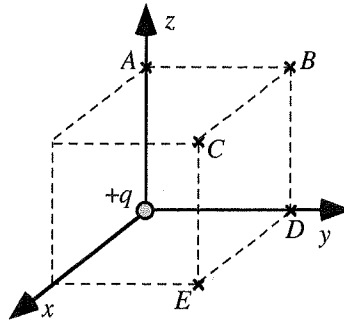
Net Force Direction	
Charge 1	
Charge 2	
Charge 3	

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	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5		All	All	Cannot
Greatest				Least		the same	zero	determine

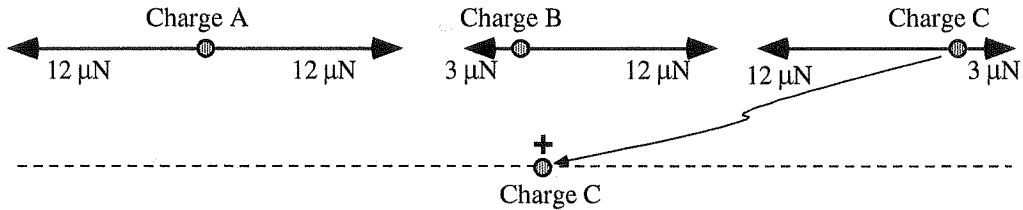
Explain your reasoning.

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

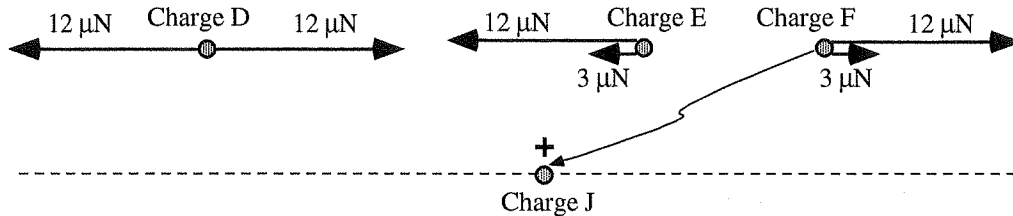
Three charges are fixed in place along a line. All three charges have the same magnitude, but they may have different signs. Shown below are diagrams showing the forces exerted on each charge by the other two charges.

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.**

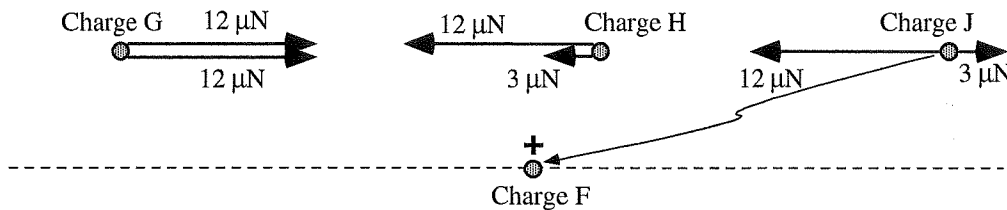
Case 1



Case 2



Case 3



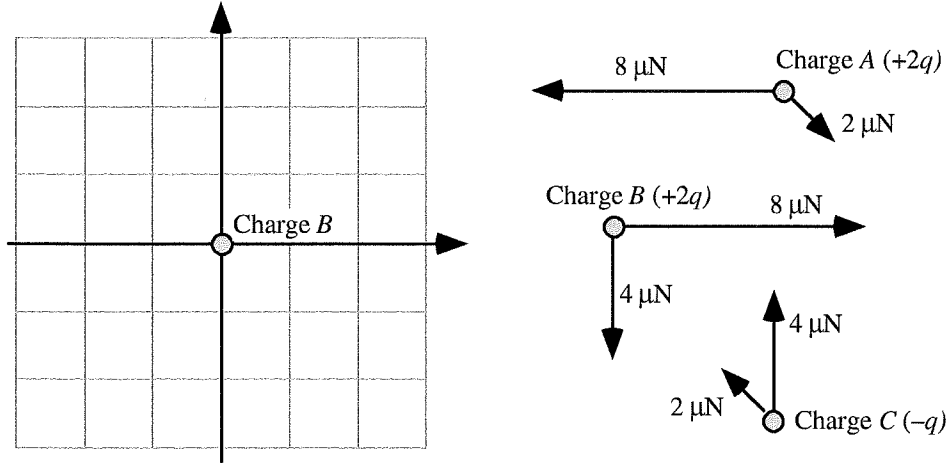
Explain your reasoning.

TIPERS

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.

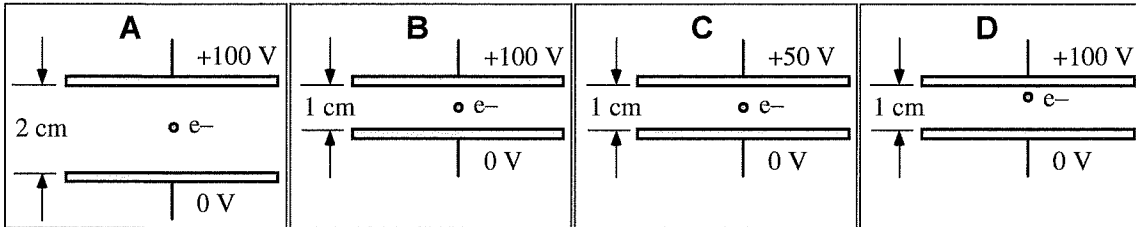
Particle *B* is shown fixed at the origin of a grid. **On the grid, indicate the positions of particles *A* and *C* relative to particle *B*.**



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.



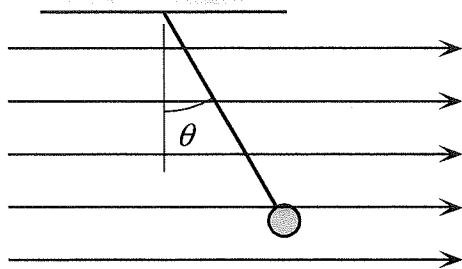
Rank the magnitude of the force exerted on the electron.

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

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

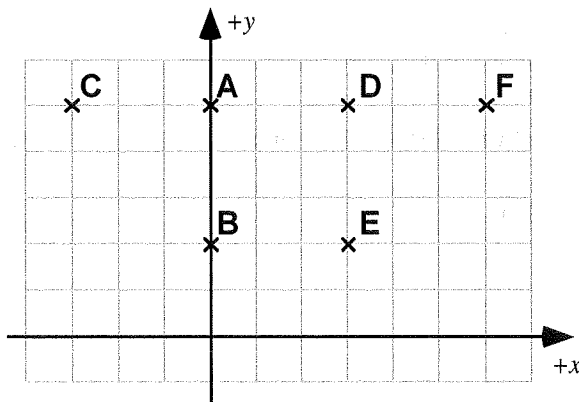
Rank the angle θ that the string forms with the vertical for these different spheres.

<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4		All	All	Cannot
Greatest			Least		the same	zero	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 (\Rightarrow). 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 $+5 \mu\text{C}$ charge when it is placed at rest at each of the labeled points.

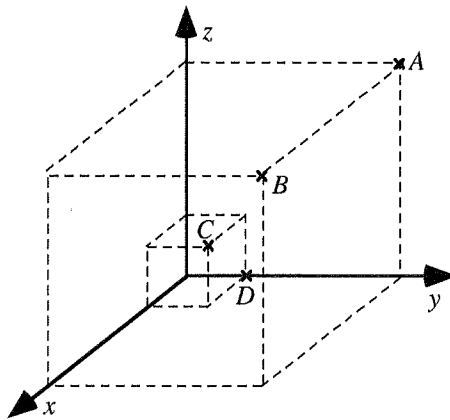
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6		All	All	Cannot
Greatest					Least		the same	zero	determine

Explain your reasoning.

TIPERs

D1-RT45: UNIFORM ELECTRIC FIELD—ELECTRIC FORCE AT THREE-DIMENSIONAL LOCATIONS

All the labeled points are within a region of space with a uniform electric field. The electric field points toward the top of the page (that is, in the positive z -direction).



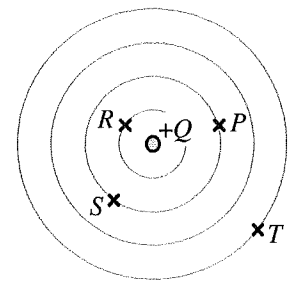
Rank the magnitude of the electric force on a charge of $+2 \mu\text{C}$ at the labeled points.

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

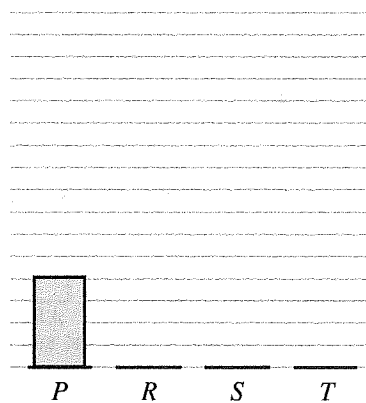
Explain your reasoning.

D1-BCT46: POINT CHARGE—ELECTRIC FIELD

Points P , R , S , and T lie close to a positive point charge. The concentric circles shown are equally spaced with radii of r , $2r$, $3r$, and $4r$. The magnitude of the electric field at point P due to the point charge is shown in the bar chart below.



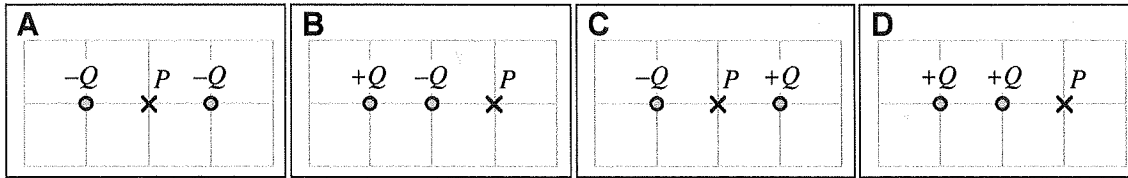
Magnitude of electric field



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 .

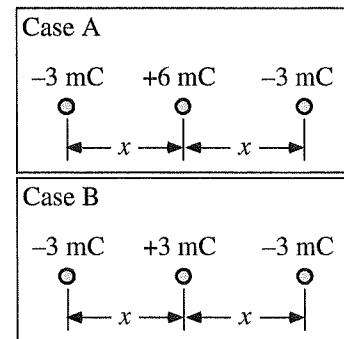
				OR			
1	2	3	4		All the same	All zero	Cannot determine
Greatest							Least

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 its 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?

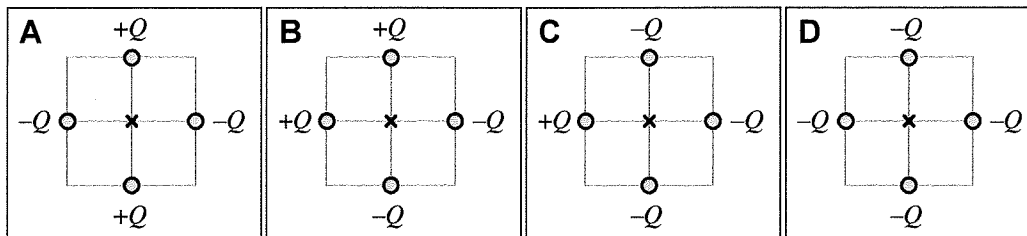
Adrianna _____ Brandon _____ Catalina _____ None of them _____

Explain your reasoning.

TIPERS

D1-RT49: FOUR POINT CHARGES IN TWO DIMENSIONS—ELECTRIC FIELD

In each case, four charged particles, each with a charge magnitude Q , are fixed on grids. The cases are identical except for the signs of the charges.



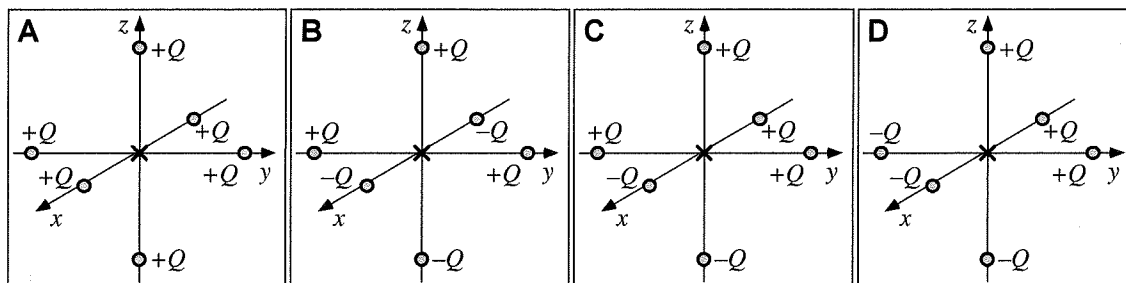
Rank the magnitude of the electric field at the location marked with an "x."

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

Explain your reasoning.

D1-RT50: SIX CHARGES IN THREE DIMENSIONS—ELECTRIC FIELD

In each case, six point charges are all the same distance from the origin as shown. All charges are either $+Q$ or $-Q$.



Rank the magnitude of the electric field at the origin.

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

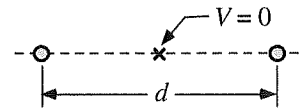
Explain your reasoning.

D1-TT51: POTENTIAL NEAR TWO CHARGES—ELECTRIC FIELD

Two equal magnitude electric charges are separated by a distance d . The electric potential at the midpoint between these two charges is zero. A student considering this situation says:

“The electric field at the midpoint between the two charges will be zero also, since the two charges are opposite in sign, so the fields will be equal but opposite, and add to zero.”

There is something wrong with the student’s statement. **Identify any problem(s) and explain how to correct it/them.**

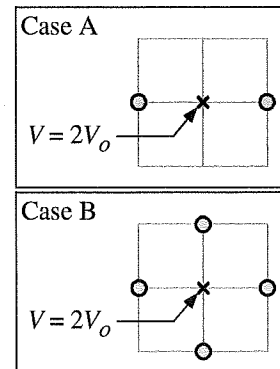


D1-CT52: POTENTIAL NEAR CHARGES—ELECTRIC FIELD

In each case, a point midway between equal magnitude electric charges is identified. The signs of these charges are not given. The electric potential at this midpoint is $2V_0$ in both cases, where V_0 is the potential due to a single positive charge.

Is the magnitude of the electric field at the midpoint (i) *greater in Case A*, (ii) *greater in Case B*, or (iii) *the same in both cases*? _____

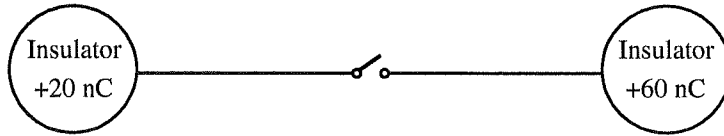
Explain your reasoning.



TIPERs

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.”*

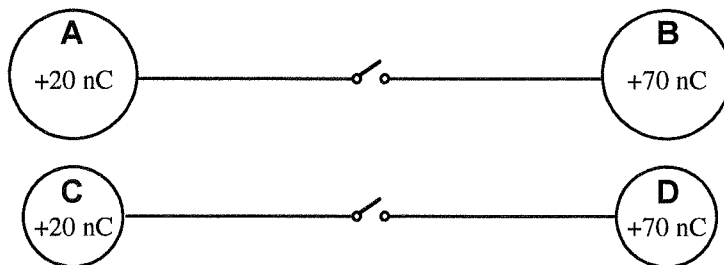
With which of these students do you agree?

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.



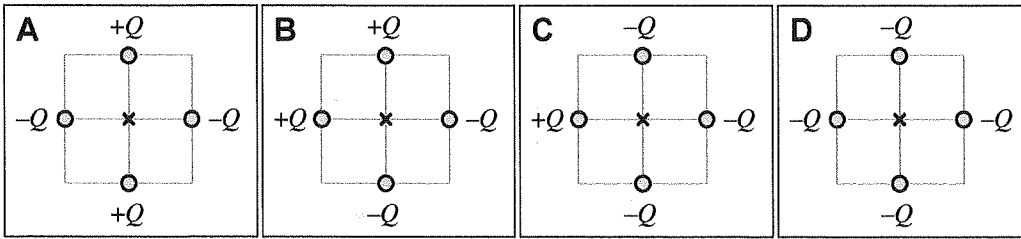
Rank the electric charge on the spheres after the switches are closed.

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

Explain your reasoning.

D1-RT55: FOUR CHARGES IN TWO DIMENSIONS—ELECTRIC POTENTIAL

In each situation shown below, small charged particles are fixed on grids having the same spacing. Each charge Q on this page has the same magnitude with the signs indicated in the diagrams.



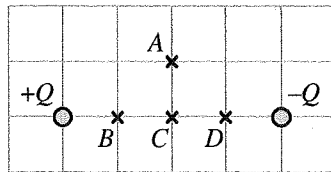
Rank the electric potential at the location marked with an "x."

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

Explain your reasoning.

D1-RT56: POINTS NEAR A PAIR OF EQUAL OPPOSITE CHARGES—ELECTRIC POTENTIAL

Two equal and opposite charges are fixed to a grid at the locations shown. Four points in the vicinity of these charges are labeled A–D.



Rank the electric potential at the labeled points.

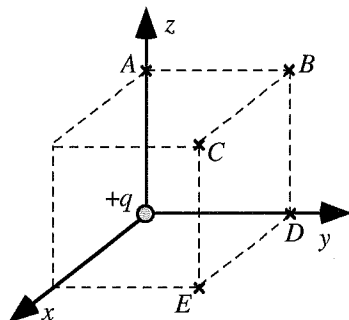
				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

TIPERS

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.



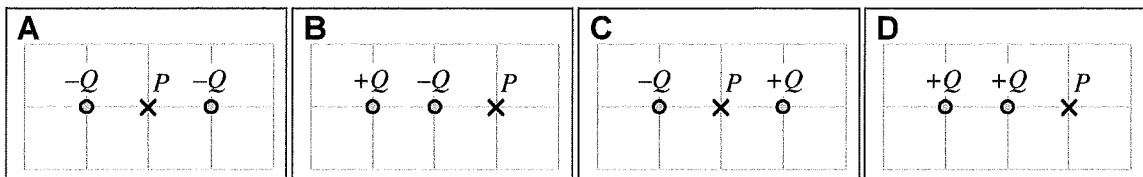
Rank the electric potential at the labeled points.

<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	OR	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>
1	2	3	4	5		All the same	All zero	Cannot determine
Greatest					Least			

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 .

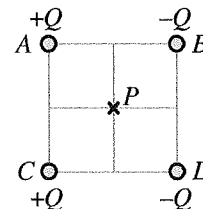
<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	OR	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	
1	2	3	4		All the same	All zero	Cannot determine	
Greatest					Least			

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.

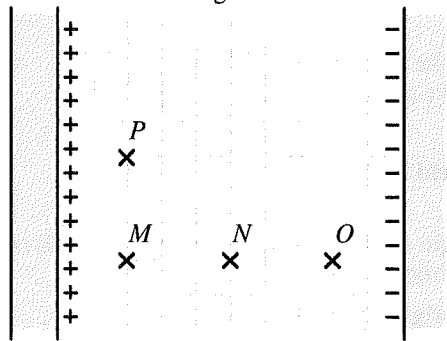
	Modification	Electric field	Electric potential	Electric field direction
(a)	Change the sign of charge A .			
(b)	Change the sign of charge B .			
(c)	Change the sign of charge C .			
(d)	Change the sign of charge D .			
(e)	Change the signs of charges B and D .			
(f)	Exchange charges A and B .			
(g)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

Explain your reasoning.

TIPERS

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 $(2, 0) \text{ m}$; N at $(5, 0) \text{ m}$; O at $(8, 0) \text{ m}$; and P at $(2, 3) \text{ m}$ within this region. (Positive values are larger than negative values.)

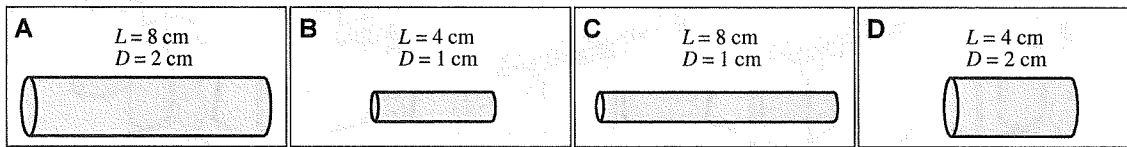
1	2	3	4	5	6	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Greatest					Least		All the same	All zero	Cannot determine

Explain your reasoning.

D2 CIRCUITS

D2-RT01: CARBON RESISTORS—RESISTANCE

Four different resistors are created from the same piece of carbon. The length and the diameter of each resistor are shown.



Rank the resistance of the four resistors.

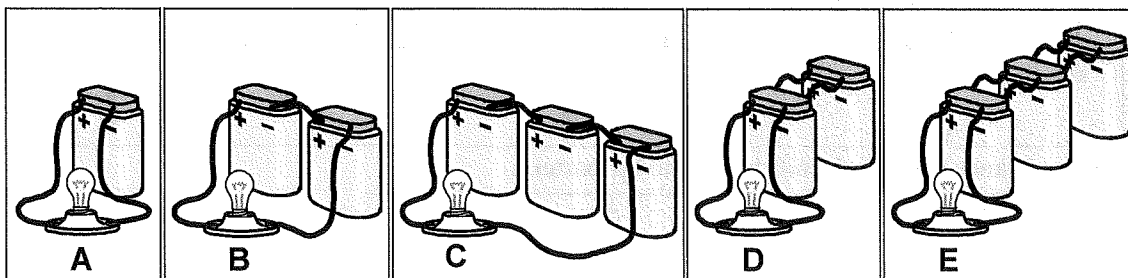
				OR			
1	2	3	4		All the same	All zero	Cannot determine
Greatest			Least				

Explain your reasoning.

D2-WWT02: BATTERIES AND LIGHT BULBS—BULB BRIGHTNESS

All of the batteries in the circuits shown are identical, as are the light bulbs. A student comparing the brightness of the bulbs in these circuits states:

“Bulbs E and C are the brightest since they have three batteries, then bulbs B and D since they have two batteries, and the least bright one is A, since there is only one battery. The more batteries, the brighter the bulb, and it does not matter how they are connected.”

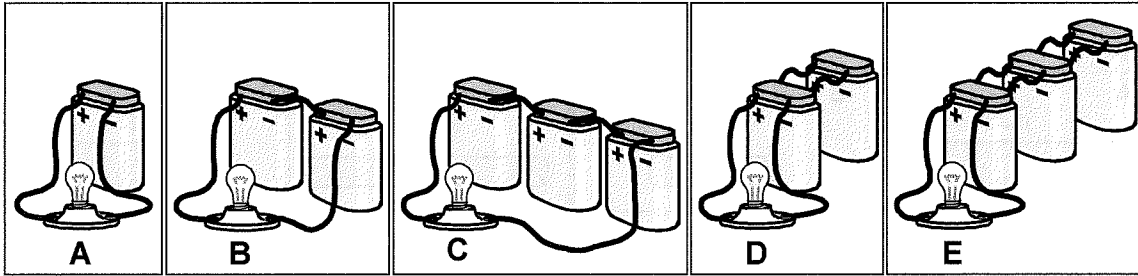


What, if anything, is wrong with this statement? If something is wrong, explain the error and how to correct it. If the statement is correct, explain why.

TIPERS

D2-RT03: BATTERIES AND LIGHT BULBS—BULB BRIGHTNESS

Identical ideal batteries are connected in different arrangements to identical light bulbs as shown.



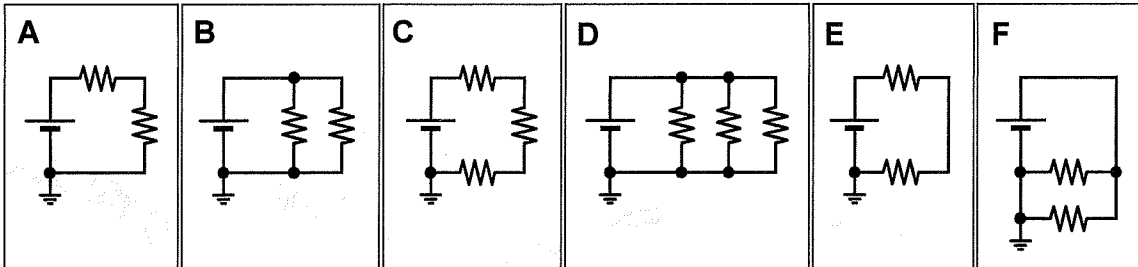
Rank the brightness of the light bulbs.

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

Explain your reasoning.

D2-RT04: SIMPLE RESISTOR CIRCUITS I—RESISTANCE

All of the resistors and batteries are identical in the circuits shown.



Rank the resistance that the circuits present to the battery.

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

Explain your reasoning.

D2-RT05: SIMPLE LIGHT BULB CIRCUITS I—BULB BRIGHTNESS

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the three items below, rank the brightness of the bulb labeled X.

(a)

A	B	C
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR

<input style="width: 30px; height: 20px;" type="text"/>	<input style="width: 30px; height: 20px;" type="text"/>	<input style="width: 30px; height: 20px;" type="text"/>
All	All	Cannot
the same	zero	determine

Explain your reasoning.

(b)

A	B	C
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR

<input style="width: 30px; height: 20px;" type="text"/>	<input style="width: 30px; height: 20px;" type="text"/>	<input style="width: 30px; height: 20px;" type="text"/>
All	All	Cannot
the same	zero	determine

Explain your reasoning.

(c)

A	B	C
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR

<input style="width: 30px; height: 20px;" type="text"/>	<input style="width: 30px; height: 20px;" type="text"/>	<input style="width: 30px; height: 20px;" type="text"/>
All	All	Cannot
the same	zero	determine

Explain your reasoning.

TIPERS

D2-RT06: SIMPLE LIGHT BULB CIRCUITS II—BULB BRIGHTNESS

All of the bulbs in the circuits below are identical, as are all of the batteries.

In each of the items below rank the brightness of the bulb labeled *X*.

(a)

A	B	C
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR All the same All zero Cannot determine

Explain your reasoning.

(b)

A	B	C
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR All the same All zero Cannot determine

Explain your reasoning.

(c)

A	B	C
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR All the same All zero Cannot determine

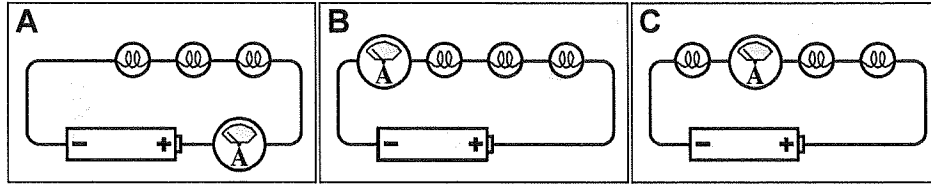
Explain your reasoning.

D2-RT07: SIMPLE LIGHT BULB CIRCUITS I—AMMETER READING

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below rank the current measured by the ammeter.

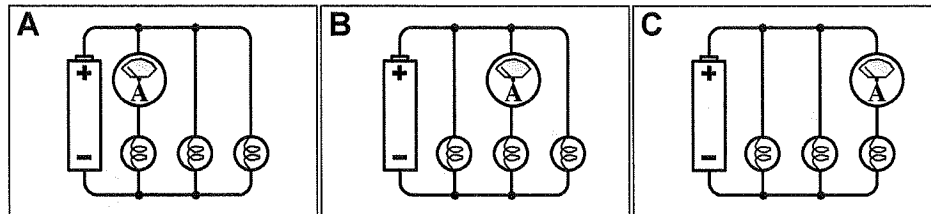
(a)



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

Explain your reasoning.

(b)



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

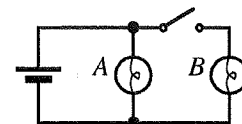
Explain your reasoning.

D2-CT08: CIRCUIT WITH TWO LIGHT BULBS—CURRENT IN BULB

A battery is connected to a circuit with two bulbs and a switch as shown.

When the switch is closed, does the current in bulb A (a) *increase*, (b) *decrease*, or (c) *remain the same*? _____

Explain your reasoning.



TIPERS

D2-RT09: SIMPLE LIGHT BULB CIRCUITS II—AMMETER READING

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below rank the current measured by the ammeter.

(a)

A

B

C

1

2

3

OR

All
the same

All
zero

Cannot
determine

1
Greatest

2

3
Least

All
the same

All
zero

Cannot
determine

Explain your reasoning.

(b)

A

B

C

1

2

3

OR

All
the same

All
zero

Cannot
determine

1
Greatest

2

3
Least

All
the same

All
zero

Cannot
determine

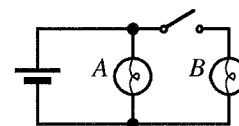
Explain your reasoning.

D2-CT10: CIRCUIT WITH TWO LIGHT BULBS—CURRENT IN BATTERY

A battery is connected to a circuit with two bulbs and a switch as shown.

When the switch is closed, does the current in the battery (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.



D2-RT11: SIMPLE LIGHT BULB CIRCUITS I—POTENTIAL DIFFERENCE BETWEEN TWO POINTS

All of the bulbs in the circuits below are identical, as are all of the batteries.

In each item below, rank the magnitude of the potential difference between points *M* and *N*.

(a)

A	B	C	D
<input style="width: 40px; height: 20px;" type="text"/>	<input style="width: 40px; height: 20px;" type="text"/>	<input style="width: 40px; height: 20px;" type="text"/>	<input style="width: 40px; height: 20px;" type="text"/>
1	2	3	4
Greatest		Least	

OR All the same All zero Cannot determine

Explain your reasoning.

(b)

A	B	C
<input style="width: 40px; height: 20px;" type="text"/>	<input style="width: 40px; height: 20px;" type="text"/>	<input style="width: 40px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR All the same All zero Cannot determine

Explain your reasoning.

(c)

A	B	C
<input style="width: 40px; height: 20px;" type="text"/>	<input style="width: 40px; height: 20px;" type="text"/>	<input style="width: 40px; height: 20px;" type="text"/>
1	2	3
Greatest		Least

OR All the same All zero Cannot determine

Explain your reasoning.

TIPERs

D2-RT12: SIMPLE LIGHT BULB CIRCUITS II—POTENTIAL DIFFERENCE BETWEEN TWO POINTS

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below, rank the magnitude of the potential difference between points *M* and *N*.

(a)

A	B	C
<input type="text"/>	<input type="text"/>	<input type="text"/>
1	2	3
Greatest		Least

OR

<input type="text"/>	<input type="text"/>	<input type="text"/>
All	All	Cannot
the same	zero	determine

Explain your reasoning.

(b)

A	B	C
<input type="text"/>	<input type="text"/>	<input type="text"/>
1	2	3
Greatest		Least

OR

<input type="text"/>	<input type="text"/>	<input type="text"/>
All	All	Cannot
the same	zero	determine

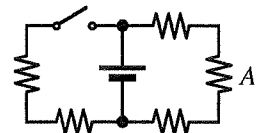
Explain your reasoning.

D2-CT13: RESISTOR CIRCUIT WITH SWITCH—CURRENT

Five identical resistors and a switch are connected to a battery as shown.

When the switch closes, will the current in resistor *A* (i) increase, (ii) decrease, or (iii) remain the same? _____

Explain your reasoning.

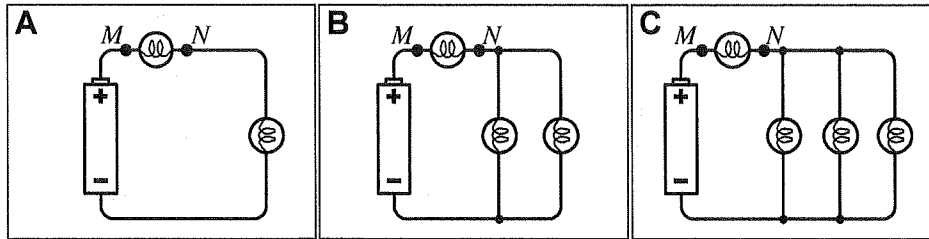


D2-RT14: SIMPLE LIGHT BULB CIRCUITS III—POTENTIAL DIFFERENCE BETWEEN TWO POINTS

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below, rank the magnitude of the potential difference between points *M* and *N*.

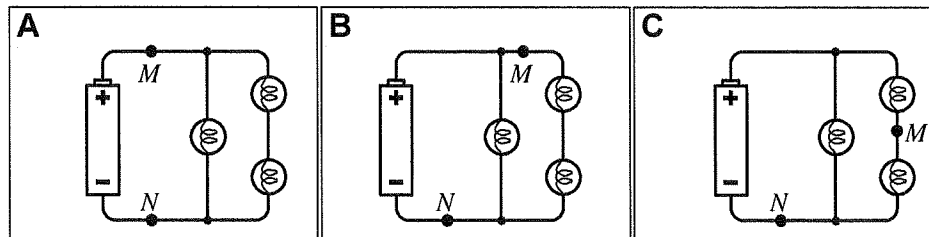
(a)



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

Explain your reasoning.

(b)



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

Explain your reasoning.

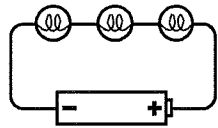
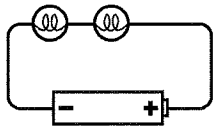
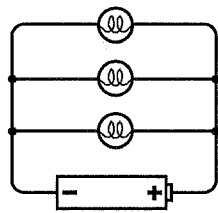
TIPERS

D2-RT15: SIMPLE LIGHT BULB CIRCUITS I—CURRENT IN BATTERY

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below, rank the current in the battery.

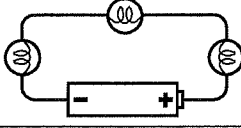
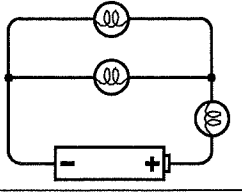
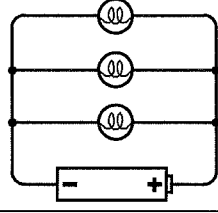
(a)

A 	B 	C 
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1 Greatest	2	3 Least

OR All the same All zero Cannot determine

Explain your reasoning.

(b)

A 	B 	C 
<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>	<input style="width: 50px; height: 20px;" type="text"/>
1 Greatest	2	3 Least

OR All the same All zero Cannot determine

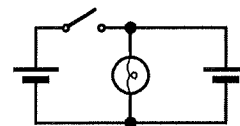
Explain your reasoning.

D2-CT16: CIRCUIT WITH TWO BATTERIES—BULB BRIGHTNESS

Two identical ideal batteries, a switch, and a bulb are connected as shown.

When the switch closes, will the brightness of the bulb (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

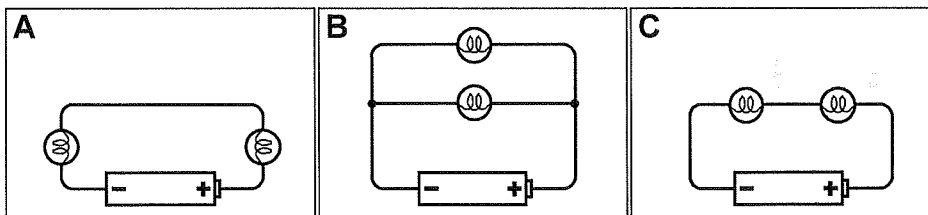


D2-RT17: SIMPLE LIGHT BULB CIRCUITS II—CURRENT IN BATTERY

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below, rank the current in the battery.

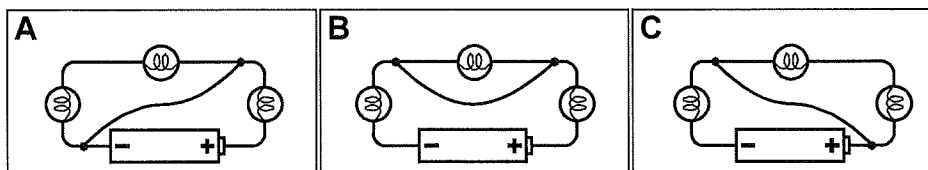
(a)



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

Explain your reasoning.

(b)



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

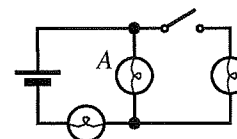
Explain your reasoning.

D2-CT18: LIGHT BULB CIRCUIT WITH SWITCH—CURRENT IN BULB

Three light bulbs and a switch are connected to a battery as shown.

When the switch is closed, will the current in bulb A (i) increase, (ii) decrease, or (iii) remain the same? _____

Explain your reasoning.

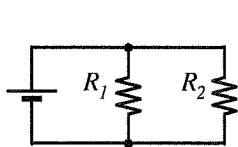


TIPERs

D2-QRT19: TWO RESISTOR CIRCUITS—CURRENT, RESISTANCE, AND VOLTAGE DROP CHART

For items (a) and (b) below complete the table, showing the value of the currents in and voltages across all elements.

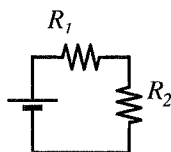
(a) The resistance values for this circuit are given in the table, as is the battery voltage.



	ΔV	I	R
Battery	15.0 V		
R_1			5.0 Ω
R_2			3.0 Ω

Explain your reasoning.

(b) The resistance values for this circuit are given in the table, as is the current in the battery.



	ΔV	I	R
Battery		4.0 A	
R_1			2.0 Ω
R_2			1.0 Ω

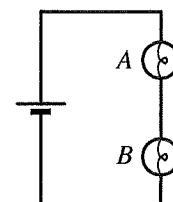
Explain your reasoning.

D2-CT20: TWO LIGHT BULBS IN A CIRCUIT—BULB BRIGHTNESS

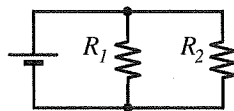
Two identical light bulbs are connected to a battery as shown.

Is bulb A (i) *brighter than*, (ii) *dimmer than*, or (iii) *the same brightness as* bulb B? _____

Explain your reasoning.



D2-LMCT21: TWO RESISTORS IN PARALLEL—BATTERY CURRENT



For the circuit shown, identify, from choices (i)–(iv), how each change described below will affect the current in the battery.

This change will:

- (i) *increase* the current in the battery.
- (ii) *decrease* the current in the battery.
- (iii) *have no effect* on the current in the battery.
- (iv) have an effect on the current in the battery that *cannot be determined*.

All of these modifications are changes to the initial situation that is shown.

(a) The resistance in R_1 is reduced. _____
Explain your reasoning.

(b) The resistance in R_2 is reduced. _____
Explain your reasoning.

(c) The resistance in R_1 and R_2 are increased by the same amount. _____
Explain your reasoning.

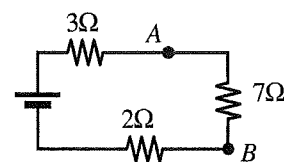
(d) The resistance in R_1 is reduced, and in R_2 it is increased. _____
Explain.

D2-CT22: CIRCUIT WITH THREE RESISTORS—CURRENT

Three resistors are connected to a battery as shown. Two points in the circuit are labeled A and B .

Is the current at point A (i) *greater than*, (ii) *less than*, or (iii) *equal to* the current at point B ? _____

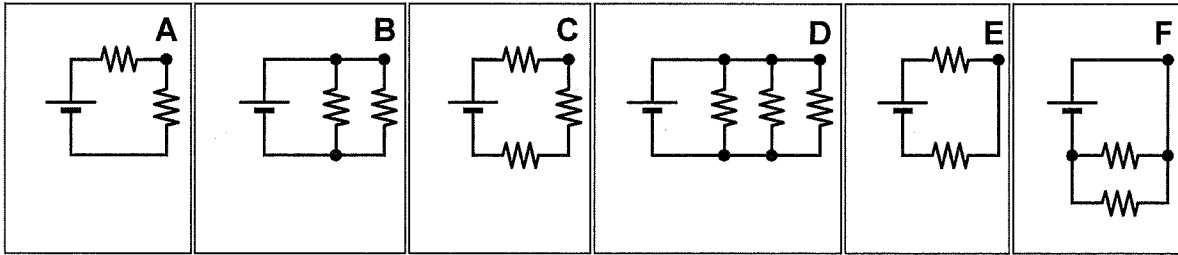
Explain your reasoning.



TIPERS

D2-RT23: SIMPLE RESISTOR CIRCUITS I—CURRENT

All of the resistors in the circuits shown are identical, as are all of the batteries.



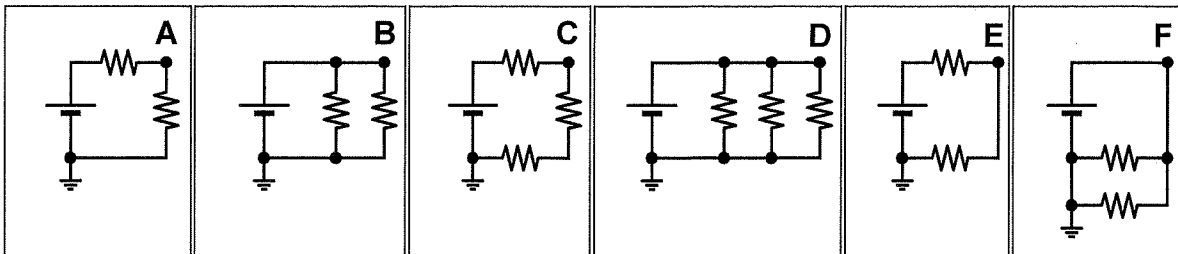
Rank the current at the upper right-hand corner of each circuit.

1	2	3	4	5	6	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Greatest					Least		All the same	All zero	Cannot determine

Explain your reasoning.

D2-RT24: SIMPLE RESISTOR CIRCUITS WITH A GROUND—VOLTAGE

All of the resistors in the circuits below are identical, as are all of the batteries.



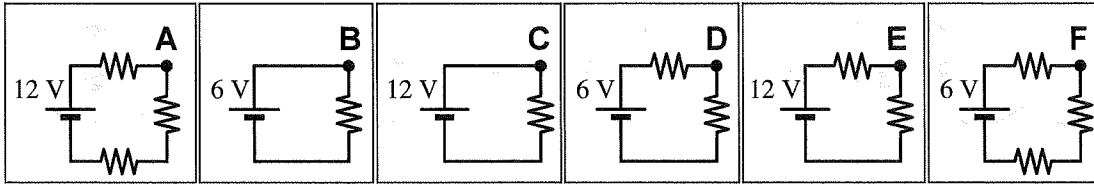
Rank the voltage at the upper right-hand corner of the circuits relative to ground.

1	2	3	4	5	6	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Greatest					Least		All the same	All zero	Cannot determine

Explain your reasoning.

D2-RT25: SIMPLE RESISTOR CIRCUITS II—CURRENT

All of the resistors in the circuits below are identical. Three of the circuits contain 6-volt batteries and three contain 12-volt batteries.



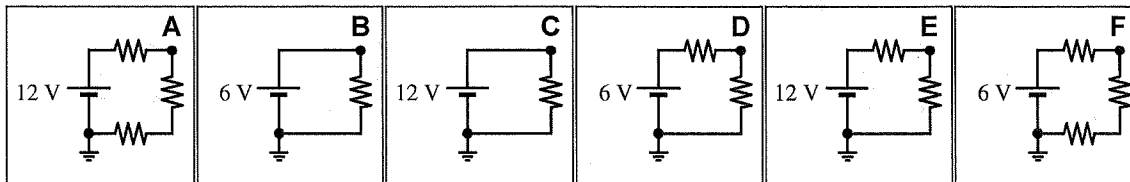
Rank the current at the upper right-hand corner of each circuit.

1	2	3	4	5	6	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Greatest					Least		All the same	All zero	Cannot determine

Explain your reasoning.

D2-RT26: SIMPLE RESISTOR CIRCUITS WITH A GROUND—VOLTAGE DROP

The following circuits contain either a 6-volt or a 12-volt battery and one or more identical resistors.



Rank the reading on a voltmeter connected between the upper right-hand corner and ground.

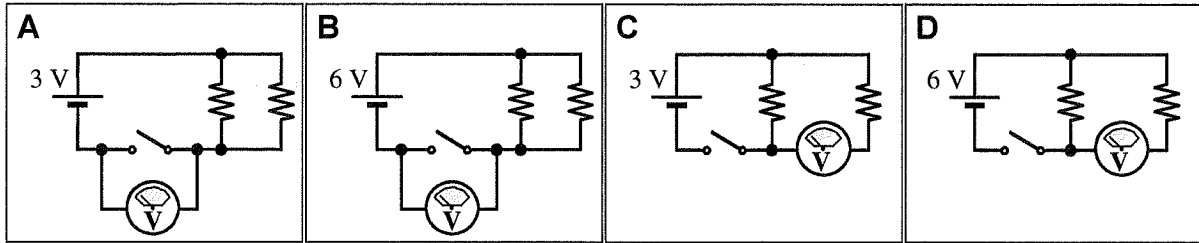
1	2	3	4	5	6	OR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Greatest					Least		All the same	All zero	Cannot determine

Explain your reasoning.

TIPERS

D2-RT27: PARALLEL CIRCUITS I—VOLTMETER READINGS ACROSS OPEN SWITCHES

All of the resistors in the circuits below are identical. The switch in each case is open.



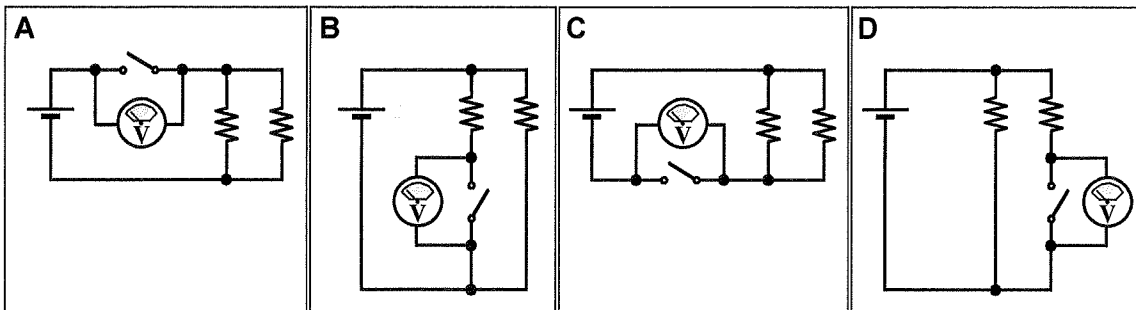
Rank the voltmeter readings.

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

Explain your reasoning.

D2-RT28: PARALLEL CIRCUITS II—VOLTMETER READINGS ACROSS OPEN SWITCHES

All of the resistors in the circuits below are identical, as are all of the batteries. The switch in each case is open.



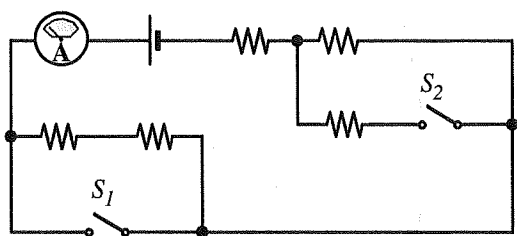
Rank the voltmeter readings.

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

Explain your reasoning.

D2-RT29: CIRCUIT WITH TWO SWITCHES—AMMETER READINGS

The circuit contains a battery, two switches, five identical resistors, and an ammeter. Four possible switch configurations (open or closed) for the circuit are shown in the table.



Configuration	Switch S_1	Switch S_2
A	Open	Open
B	Open	Closed
C	Closed	Open
D	Closed	Closed

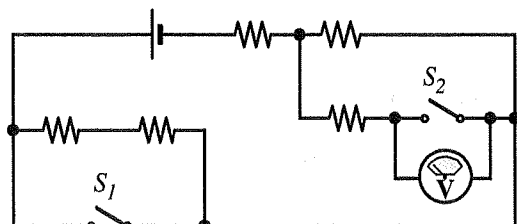
Rank the ammeter reading for the four configurations.

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

Explain your reasoning.

D2-RT30: CIRCUIT WITH TWO SWITCHES—VOLTMETER READINGS

The circuit contains a battery, two switches, five identical resistors, and a voltmeter. Four possible switch configurations (open or closed) for the circuit are shown in the table.



Configuration	Switch S_1	Switch S_2
A	Open	Open
B	Open	Closed
C	Closed	Open
D	Closed	Closed

Rank the voltmeter reading for the four configurations.

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

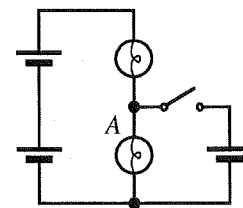
Explain your reasoning.

D2-CT33: LIGHT BULBS CIRCUIT WITH THREE BATTERIES—BULB BRIGHTNESS

Three identical ideal batteries, a switch, and two bulbs are connected as shown.

When the switch closes, will the brightness of bulb A (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

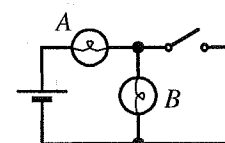


D2-CT34: LIGHT BULBS CIRCUIT WITH SWITCH—BRIGHTNESS OF BULBS

Two light bulbs and a switch are connected to a battery as shown.

(a) When the switch is closed, will the brightness of bulb B (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.



(b) When the switch is closed, will the brightness of bulb A (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

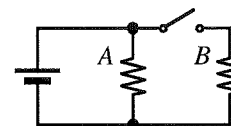
Explain your reasoning.

D2-WWT35: CIRCUIT WITH TWO RESISTORS—CURRENT

A battery is connected to a circuit containing two resistors and a switch as shown. A student states:

“When the switch closes, the current in resistor A goes down, because resistor A now has to share the current from the battery with resistor B.”

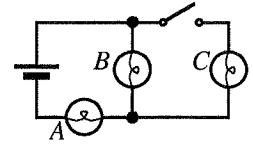
What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.



TIPERs

D2-SCT36: LIGHT BULB CIRCUIT WITH SWITCH—BULB BRIGHTNESS

Three light bulbs and a switch are connected to a battery as shown. Four students are discussing what would happen to the brightness of bulb A when the switch closes:



Althea: *“The current in bulb A has to be the same as the current in the battery, since they are in the same branch. The battery is going to put out the same current whether the switch is open or closed, so the current in bulb A is going to remain the same, and its brightness won’t change when the switch closes.”*

Bertha: *“I agree. All that is going to happen when the switch closes is that bulb C is going to turn on, and it’s going to get half of the current. Bulb B only gets half the current as well, so it gets dimmer. But bulb A still gets all the current, and its brightness doesn’t change.”*

Cassidy: *“I think bulb A gets brighter. The current in the circuit goes up, because when the switch closes the resistance of the circuit goes down. Since bulb A gets all the current in the circuit, it gets brighter.”*

Dupree: *“When the switch closes, the resistance of the circuit goes up, because you’ve added one bulb, which has resistance. The current in the circuit goes down, and bulb A gets dimmer.”*

With which, if any, of these students do you agree?

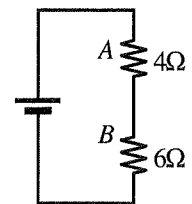
Althea _____ Bertha _____ Cassidy _____ Dupree _____ None of them _____

Explain your reasoning.

D2-WWT37: CIRCUIT WITH TWO RESISTORS—CURRENT

A battery is connected to a circuit containing two resistors as shown. A student states:

“Using Ohm’s law, the current is the voltage divided by the resistance, so when you have a bigger resistor, you have a smaller current. In this case, resistor B is a larger resistance than A, so it will have a smaller current.”



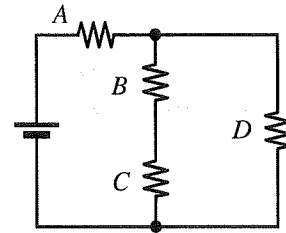
What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.

D2-WWT38: CIRCUIT WITH FOUR RESISTORS—CURRENT RANKING

A battery is connected to a circuit containing four identical resistors as shown. A student states:

“All of the current from the battery goes through resistor A. At the junction after A the current splits up. Half of the current goes through resistor D, and the other half is shared by resistors B and C. So resistor A has the most current, followed by resistor D, followed by resistors B and C, which have the same current.”

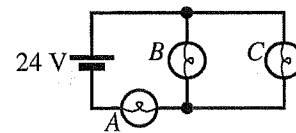
What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.

**D2-WWT39: CIRCUIT WITH THREE BULBS—VOLTAGES**

A 24-volt battery is in a circuit containing three bulbs as shown. A voltmeter across bulb A measures 18 Volts. A student states:

“Since bulbs B and C are identical, then they will each have the same current and the same voltage across them. The sum of the voltages across the three bulbs must add to the battery voltage. So bulb B has a voltage of 3 volts across it, and bulb C also has a voltage of 3 volts.”

What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.



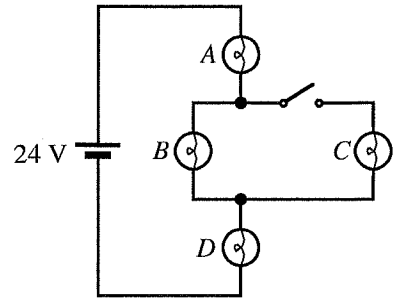
TIPERS

D2-CT40: FOUR LIGHT BULBS CIRCUIT WITH SWITCH—EFFECT OF CLOSING SWITCH

A battery is connected to four identical bulbs and a switch as shown.

(a) When the switch is closed, does the brightness of bulb C (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.



(b) When the switch is closed, does the current in the battery (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

(c) When the switch is closed, does the brightness of bulb A (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

(d) When the switch is closed, is bulb D (i) *brighter* than bulb A, (ii) *dimmer* than bulb A, or (iii) *the same* brightness as bulb A? _____

Explain your reasoning.

(e) When the switch is closed, does the brightness of bulb D (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

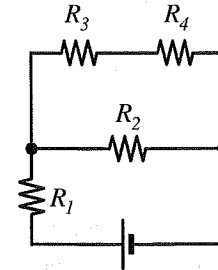
Explain your reasoning.

(f) When the switch is closed, does the brightness of bulb B (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

D2-SCT41: FOUR RESISTOR CIRCUIT I—CURRENT

In the circuit shown, the sizes of the resistors vary as $R_3 > R_1 > R_2 > R_4$. Four students discussing the currents in this circuit make the following statements:



- Ajay: "I think the current in R_1 will be the largest because all of the current from the battery goes through it."
- Belen: "Right, and after R_1 the current splits into two parts at the junction. The current through R_2 , R_3 , and R_4 will all be the same because there are two branches in the circuit and each branch will get half of the current."
- Ciara: "From Ohm's law, current is biggest where resistance is smallest. I think the current through R_2 will be largest because that branch has the lowest resistance in the circuit."
- Damaris: "Also using Ohm's law, I think the current in R_3 will be the smallest because R_3 has the largest resistance. The current in R_4 will be largest, because that resistor has the smallest resistance."
- Efren: "The current in R_3 will be the same as the current in R_4 because they are in the same branch."

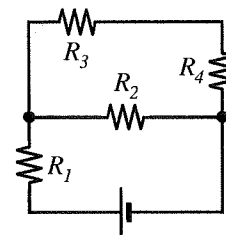
With which, if any, of these students do you agree?

Ajay _____ Belen _____ Ciara _____ Damaris _____ Efren _____ None of them _____

Explain your reasoning.

D2-SCT42: FOUR RESISTOR CIRCUIT II—CURRENT

In the circuit shown, the sizes of the resistors vary as $R_3 > R_2 > R_4 > R_1$. Four students discussing the currents in this circuit make the following statements:



- Ali: "I think the current in R_1 will be the largest because all of the current from the battery goes through it."
- Ben: "I think the current through R_2 , R_3 , and R_4 will all be the same because there are two branches in the circuit and each branch will get half of the current."
- Clyde: "Well I disagree with Ben. I think the current in R_2 will be larger than the current in R_3 and R_4 . The currents in the branches depend on the resistances of the branches."
- Dar: "The only thing I am sure about is that the current in R_3 will be the same as that in R_4 because they are in the same branch."

With which, if any, of these students do you agree?

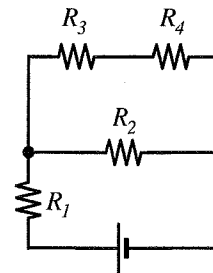
Ali _____ Ben _____ Clyde _____ Dar _____ None of them _____

Explain your reasoning.

TIPERS

D2-SCT43: FOUR RESISTOR CIRCUIT III—POTENTIAL DIFFERENCE

In the circuit shown, the sizes of the resistors vary as $R_3 > R_1 > R_2 > R_4$. Four students discussing the potential differences in this circuit make the following statements:



Anselma: *“I think the potential difference across R_1 will be the largest because all of the current from the battery goes through it, and it is not the smallest resistance in the circuit.”*

Brooke: *“I think the potential difference through R_2 will be largest because that branch will have the larger current of the two branches in the circuit.”*

Chandra: *“I am not sure about the potential difference across R_1 , but I think the potential differences across the two horizontal branches will be the same.”*

Deangelo: *“I’m pretty sure the potential difference across R_3 will be larger than the potential difference across R_4 , because R_3 has a larger resistance than R_4 .”*

Eloy: *“I think the two horizontal branches have the same potential difference as the battery since they are in parallel with the battery.”*

With which, if any, of these students do you agree?

Anselma _____ Brooke _____ Chandra _____ Deangelo _____ Eloy _____ None of them _____

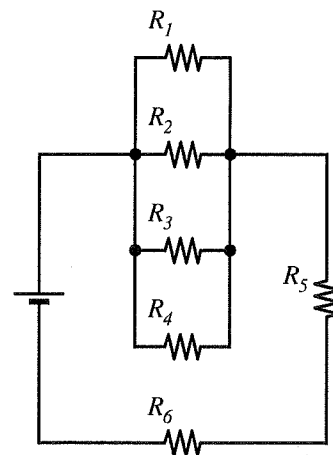
Explain your reasoning.

D2-SCT44: SIX RESISTOR CIRCUIT—CURRENT

In the circuit pictured below the sizes of the resistors vary as

$$R_3 > R_5 > R_1 > R_2 > R_4 > R_6$$

Four students discussing the currents in this circuit make the following statements:



Anne: *“I think the current in R_6 and R_5 will be the largest because all of the current from the battery goes through both of those resistors.”*

Benicio: *“I think the current through R_6 will be the smallest because that resistor is the last one in the circuit to get the current, and it is the smallest resistor.”*

Celestine: *“I am not sure about the largest current, but I think the current in R_3 will be the lowest because R_3 has the largest resistance.”*

Dulce: *“The only thing I am sure about is that the current across R_6 will be the largest because it is the smallest resistor in the circuit.”*

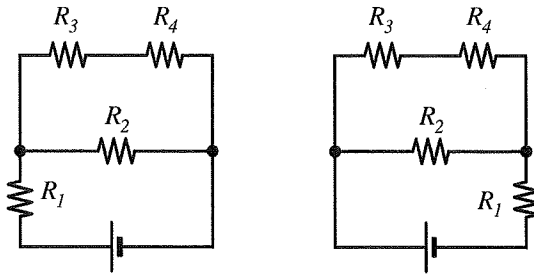
With which, if any, of these students do you agree?

Anne _____ Benicio _____ Celestine _____ Dulce _____ None of them _____

Explain your reasoning.

D2-CT45: FOUR RESISTOR CIRCUITS III—CURRENT

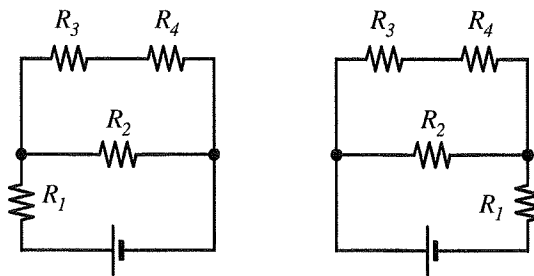
For these two circuits, consider the current in the resistor R_1 closest to the battery.



Will the current in R_1 be (i) *larger* in the circuit on the left, (ii) *smaller* in the circuit on the left, or (iii) *equal* in both circuits? _____
 Explain your reasoning.

D2-CT46: FOUR RESISTOR CIRCUITS III—POTENTIAL DIFFERENCE

For these two circuits, consider the potential difference across the resistor R_1 closest to the battery.



Will the potential difference across R_1 be (i) *larger* in the circuit on the left, (ii) *smaller* in the circuit on the left, or (iii) *equal* in both? _____
 Explain your reasoning.

TIPERS**D2-WBT47: THREE RESISTORS CIRCUIT CHART I—CIRCUIT**

A circuit contains three resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	36.0 V	3.0 A	
R_1	9.0 V	3.0 A	3.0 Ω
R_2	15.0 V	3.0 A	5.0 Ω
R_3	12.0 V	3.0 A	4.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

D2-WBT48: THREE RESISTORS CIRCUIT CHART II—CIRCUIT

A circuit contains three resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	24.0 V	16.0 A	
R_1	24.0 V	8.0 A	3.0 Ω
R_2	24.0 V	6.0 A	4.0 Ω
R_3	24.0 V	2.0 A	12.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

D2-WBT49: THREE RESISTORS CIRCUIT CHART III—CIRCUIT

A circuit contains three resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	18.0 V	6.0 A	
R_1	6.0 V	6.0 A	1.0 Ω
R_2	12.0 V	2.0 A	6.0 Ω
R_3	12.0 V	4.0 A	3.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

D2-WBT50: THREE RESISTORS CIRCUIT CHART IV—CIRCUIT

A circuit contains three resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	12.0 V	4.0 A	
R_1	3.0 V	3.0 A	1.0 Ω
R_2	9.0 V	3.0 A	3.0 Ω
R_3	12.0 V	1.0 A	12.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

TIPERs**D2-WBT51: FOUR RESISTORS CIRCUIT CHART I—CIRCUIT**

A circuit contains four resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	60.0 V	5.0 A	
R_1	20.0 V	2.0 A	10.0 Ω
R_2	40.0 V	2.0 A	20.0 Ω
R_3	45.0 V	3.0 A	15.0 Ω
R_4	15.0 V	3.0 A	5.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

D2-WBT52: FOUR RESISTORS CIRCUIT CHART II—CIRCUIT

A circuit contains four resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	36.0 V	9.0 A	
R_1	12.0 V	6.0 A	2.0 Ω
R_2	12.0 V	3.0 A	4.0 Ω
R_3	24.0 V	6.0 A	4.0 Ω
R_4	24.0 V	3.0 A	8.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

D2-WBT53: FIVE RESISTORS CIRCUIT CHART—CIRCUIT

A circuit contains five resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	
Battery	30.0 V	9.0 A	R
R_1	12.0 V	2.0 A	6.0Ω
R_2	12.0 V	3.0 A	4.0Ω
R_3	12.0 V	4.0 A	3.0Ω
R_4	18.0 V	3.0 A	6.0Ω
R_5	18.0 V	6.0 A	3.0Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

D2-WBT54: SIX RESISTORS CIRCUIT CHART I—CIRCUIT

A circuit contains six resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	
Battery	39.0 V	5.0 A	R
R_1	6.0 V	3.0 A	2.0Ω
R_2	6.0 V	2.0 A	3.0Ω
R_3	10.0 V	5.0 A	2.0Ω
R_4	8.0 V	4.0 A	2.0Ω
R_5	8.0 V	1.0 A	8.0Ω
R_6	15.0 V	5.0 A	3.0Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

TIPERs

D2-WBT55: SIX RESISTORS CIRCUIT CHART II—CIRCUIT

A circuit contains six resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	62.0 V	10.0 A	
R_1	12.0 V	3.0 A	4.0 Ω
R_2	12.0 V	1.0 A	12.0 Ω
R_3	12.0 V	4.0 A	3.0 Ω
R_4	12.0 V	2.0 A	6.0 Ω
R_5	20.0 V	10.0 A	2.0 Ω
R_6	30.0 V	10.0 A	3.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

D2-WBT56: SEVEN RESISTORS CIRCUIT CHART—CIRCUIT

A circuit contains seven resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	R
Battery	64.0 V	12.0 A	
R_1	20.0 V	5.0 A	4.0 Ω
R_2	20.0 V	2.0 A	10.0 Ω
R_3	20.0 V	5.0 A	4.0 Ω
R_4	24.0 V	12.0 A	2.0 Ω
R_5	8.0 V	4.0 A	2.0 Ω
R_6	8.0 V	8.0 A	1.0 Ω
R_7	12.0 V	12.0 A	1.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.