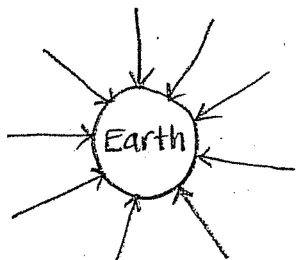
THURS APRIL 29th Electric Field + Potential Test

THE ELECTRIC FIELD

The presence of a massive body such as the earth causes objects to experience a gravitational force directed toward the earth's center.

The vector diagram of the gravitational field surrounding the earth looks like:



The space surrounding the earth is permeated by a gravitational field that's created by the earth. Any mass that is placed in this field then experiences a gravitational force due to this field.

Recall, that the gravitational field strength, g, due to a massive body like the earth is defined by:

$$g = \frac{GM}{r^2}$$

The value of g changes as you move away from the earth.

The same process is used to describe the electric field around a charge. Every charged object creates an electric field of force in the space around it. Any other charged object will experience a force of attraction or repulsion from the presence of the electric field.

The electric field strength, E, due to a charged fixed object, Q, at a distance r away from it is defined by:

$$E = \frac{kQ}{r^2}$$

E, electric field strength, units are N/C.
Continuing with the comparison to gravity a gravitational field may be found as

$$g = \frac{F_g}{m}$$

where g is the field in N/kg and m is the mass of an object in that field.
The electric field is found as:

$$E = \frac{F_e}{Q}$$

where E is the electric field in N/C and Q is the charge on the test object in the field.

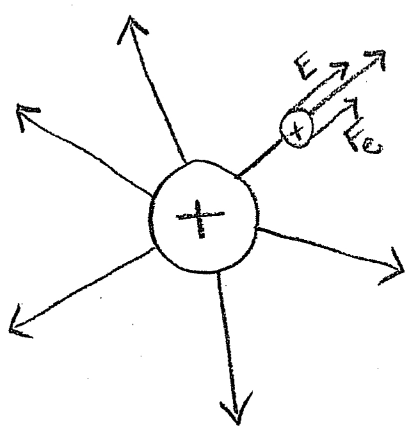
With gravity, the direction of the gravitational field was never a problem since gravity attracts, however, since electricity can attract or repel, we need to define the direction of the electric field as the direction a small positive test charge would go if placed at that point. ↳ so small doesn't alter the electric field etc in

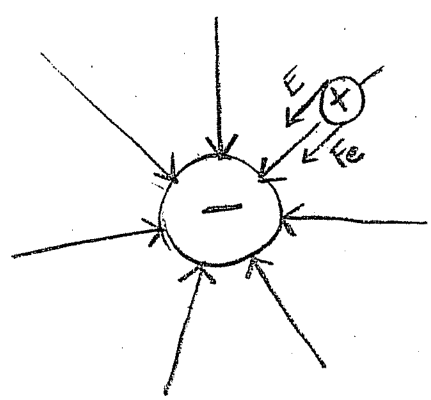
In order to visualize the electric field, we draw a series of lines to indicate the direction of the electric field at various points in space.

These lines, called electric field lines, are drawn so that

1. The electric field vector, E, is tangent to the electric field line at each point.
2. The number of lines per unit area through a surface perpendicular to the lines is proportional to the strength of the electric field in that region. Therefore E is larger when the field lines are close together and small when they are far apart.

Some electric field line diagrams are:





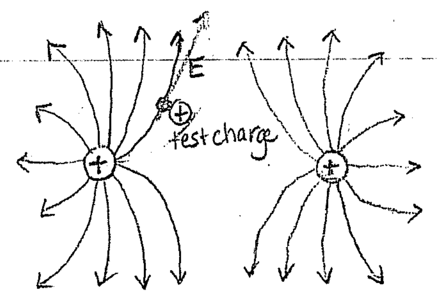
These diagrams indicate the electric field direction and the **direction of the force** on a **positive test charge** in the field at any point in space around the fixed charge. The electric field and the electric **force** on the positive test charge is always **tangent to the field lines.**

Note: The lines become more spread out the farther you get from the fixed charge. The farther apart the lines are, the weaker the electric field strength and the smaller the force placed on the test charge.

YOU could just as easily draw lines in between those shown since the electric field exerts there as well, it is continuous around the fixed charge and three dimensional.

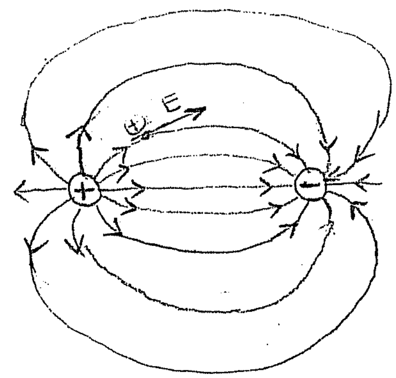
The following diagrams show the electric field lines near (a) two oppositely charged bodies, (b) two similarly charged bodies, (c) two oppositely charged bodies of unequal magnitude, and (d) two oppositely charged parallel plates.

(a)



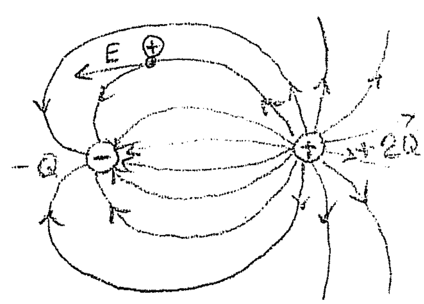
Note: The number of lines leaving the positive charge equals the number terminating at the negative charge. The high density of lines between the charges indicates a region of strong electric field.

(b)



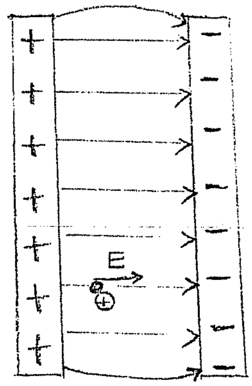
Note: The same number of lines emerge from both charges since the charges are equal in magnitude.

(c) What happens if the two charges are not of equal magnitude?



In this case, the number of lines that leave the positive charge +2q is twice the number entering the charge –q. Hence only half that leave the positive charge enter the negative charge, leaving the remaining half terminate on a negative charge we assume to be located at infinity.

(d)



Notice, that the electric field lines are perpendicular to the plates, parallel to each other and uniform or equally spaced, except near the edges. This indicates that the electric field strength is constant between the two plates.

To summarize the properties of field lines:

1. The field lines indicate the direction of the electric field; the field points in the direction tangent to the field line at any point.
2. The closer the lines the stronger the electric field strength.
3. Electric field lines start on positive charges and end on negative charges; and the number starting or ending is proportional to the magnitude of the charge, the excess lines go to infinity.
4. No two field lines can cross. **WHY?** Because the field lines represents the direction of the net force on a test charge at that location and there can't be more than one net force on any object.

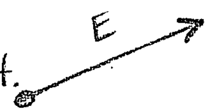
Important to note: These electric field line diagrams are stylized versions of a three dimensional and continuous field around a fixed charge

Recall, when determining the direction of an electric field force on any positive point charge, a line is drawn that is tangent and in the direction of the electric field line at any position.

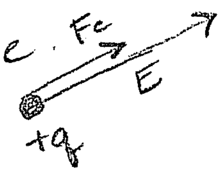
But what happens if you want to determine the direction of an electric field force on a negative test charge.

In this case the electric field force is still tangent to the direction of the electric field line, but it is pointed in the opposite direction to the electric field line.

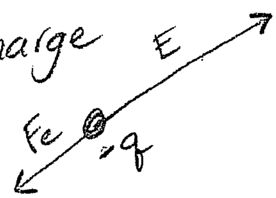
Electric Field at certain pt.

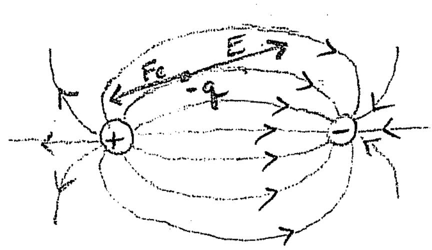


Force on positive charge.



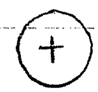
Force on negative charge





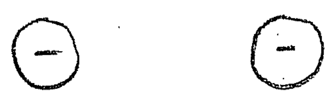
HOMEWORK

1. Draw the electric field around a positive charge.



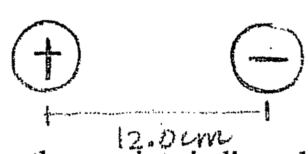
2. Draw the electric field around a negative charge

3. Draw the electric field pattern for equal like charges.

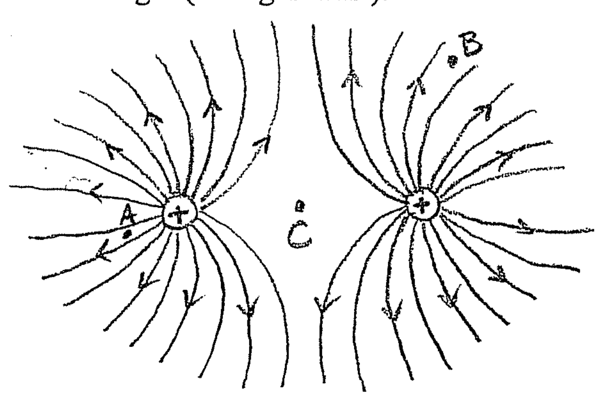


4. Draw the electric field pattern for equal and opposite charges.

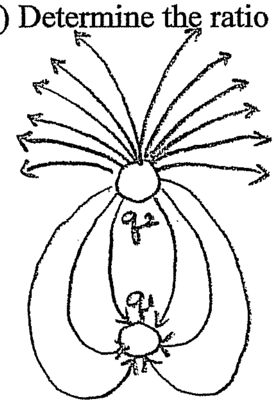
5. When determining an electric field, must we use a positive test charge, or would a negative one do as well? Explain.
6. Assume that two opposite charges are 12.0 cm apart. Consider the magnitude of the electric field 2.5 cm from the positive charge.



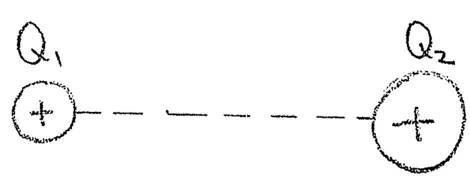
7. Consider the electric field at the three points indicated by the letters A, B, C. First draw an arrow at each point indicating the direction of the net force that a positive test charge would experience if placed at that point, then list the letter in order of decreasing field strength (strongest first).



8. Why can electric field lines never cross?
9. Consider a small positive test charge located on an electric field line. Is the direction of the force and/or acceleration of the test charge along this line? Explain.
10. Is it possible for an electric field to exist in empty space around a charge? Explain.
11. A test electron and test proton are placed in an identical electric field. Compare the electric forces on each particle.
12. Explain what happens to the magnitude of the electric field of a point charge as r approaches zero.
13. A negative charge is placed in a region of space where the electric field is directed vertically upward. What is the direction of the electric force experienced by this charge?
14. A charge 4q is at a distance r from a charge –q. Compare the number of electric field lines leaving the charge 4q with the number entering the charge –q. Where do the extra lines leaving 4q end?
15. Consider two equal point charges separated by some distance, d. At what point (other than ∞) would a third test charge experience no net force?
16. The diagram below shows the electric field lines for two point charges separated by a small distance. (a) Determine the ratio q_1/q_2. (b) What are the signs of q_1 and q_2?

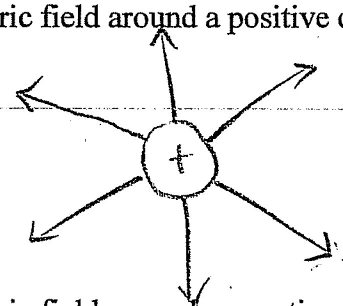


17. Describe how the electric field varies along the line from Q_1 to Q_2, if Q_1 has a larger charge than Q_2.

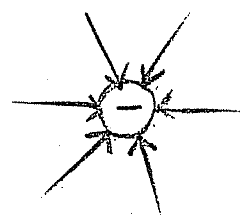


ANSWERS

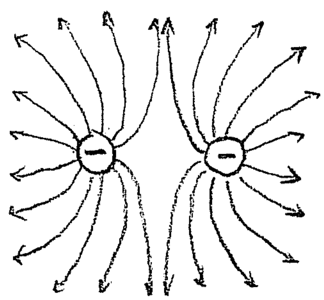
1. Draw the electric field around a positive charge.



2. Draw the electric field around a negative charge



3. Draw the electric field pattern for equal like charges.



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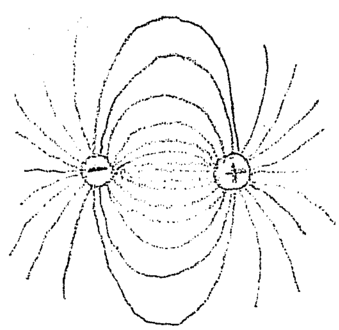
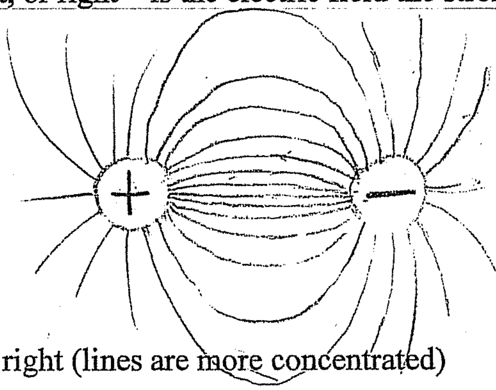


5. When determining an electric field, must we use a positive test charge, or would a negative one do as well? Explain.

A negative one would work but the field lines would point in the opposite direction to the ones for a positive test charge. By convention, the field lines are drawn so they point in the direction of the electric field for a positive test charge. Therefore if you were to draw the lines conventionally, you would need to reverse the direction of the Electric Field lines.

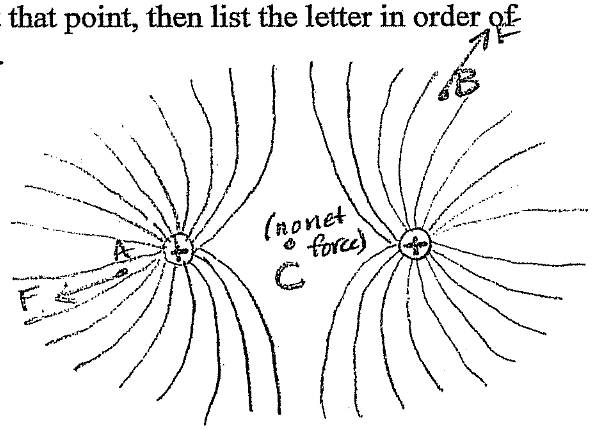
6. Assume that two opposite charges are 12.0 cm apart. Consider the magnitude of the electric field 2.5 cm from the positive charge. On which side of this charge – top, bottom, left, or right – is the electric field the strongest? Weakest?



Strongest – 2.5 cm right (lines are more concentrated)

Weakest – 2.5 cm left (lines are curling around toward the negative charge and therefore the lines are farther apart, field is weaker)

7. Consider the electric field at the three points indicated by the letters A, B, C. First draw an arrow at each point indicating the direction of the net force that a positive test charge would experience if placed at that point, then list the letter in order of decreasing field strength (strongest first).



Order of strongest to weakest – A, B, C

8. Why can electric field lines never cross?

Because the electric field lines represent the Electric field strength and direction of the Electric field at a certain point. It also represents the net force on a test charge at a certain point, and a test charge can only have one net force (magnitude and direction) acting on it at one time and place.

9. Consider a small positive test charge located on an electric field line. Is the direction of the force and/or acceleration of the test charge along this line? Explain.

Not unless the line is a straight line. Since the direction of the electric field and force is tangent to the field lines, the direction of the force can or cannot be along the line.

10. Is it possible for an electric field to exist in empty space around a charge? Explain.

Yes, it is not necessary to have a test charge to have an electric field. A charge always has an electric field around it. The test charge is just a way to prove or "see" the field.

11. A test electron and test proton are placed in an identical electric field. Compare the electric forces on each particle.

The electric force on the test electron will be in the exact opposite direction as the electric force on the test proton, but the magnitude of the force will be the same.

12. Explain what happens to the magnitude of the electric field of a point charge as r approaches zero.

The magnitude of the electric field increases as r approaches zero, either towards or away from the fixed charge.

13. A negative charge is placed in a region of space where the electric field is directed vertically upward. What is the direction of the electric force experienced by this charge?

The direction of the electric force is in the opposite direction of the electric field and therefore it is directed vertically downwards.

14. A charge 4q is at a distance r from a charge –q. Compare the number of electric field lines leaving the charge 4q with the number entering the charge –q. Where do the extra lines leaving 4q end?

The 4q charge has 4 times the number of electric field lines leaving the charge than the number entering the charge –q. The extra lines terminate on a negative charge we assume to be at infinity.

15. Consider two equal point charges separated by some distance, d. At what point (other than ∞) would a third test charge experience no net force?

Half way between them, they would experience no net force.

16. The diagram below shows the electric field lines for two point charges separated by a small distance. (a) Determine the ratio q_1/q_2. (b) What are the signs of q_1 and q_2?

(a) Ratio $q_1/q_2 = 6/18 = 1/3$ Q_2 is 3 times larger in charge than Q_1

(b) $-q_1$ and $+q_2$

17. Describe how the electric field varies along the line from Q_1 to Q_2, if Q_1 has a smaller charge than Q_2.

The electric field initially points to the right and decreases as you move along the line. At one point, closer to Q_1, the electric field will be zero. Past this point, the field is pointing to the left and increases.