Section 14: Electric Fields

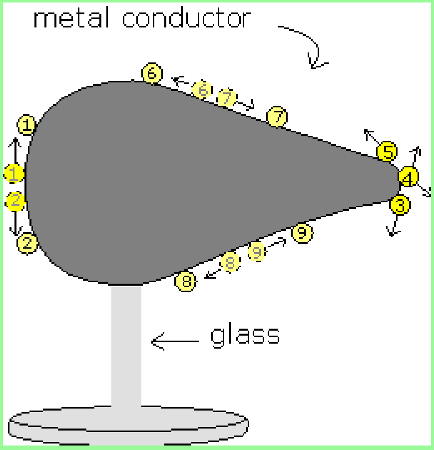
In this Section you will

- define the terms charge distribution, field, electric field, test charge, field lines, equipotential lines
- state the rules for drawing electric field lines
- sketch the electric field around different configurations of charged objects
- compare an electric field with the gravitational field of earth.

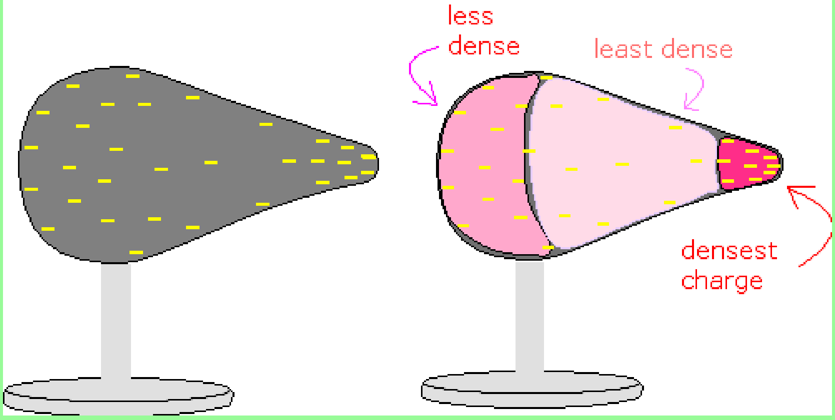
Charge distribution

Less Curvature (Straight area) - Repelling forces are more parallel to the surface and the electrons are forced further apart.

More Curvature (pointy areas) - the repelling forces are not parallel with the surfaces, so the electrons don't require as much "elbow room".

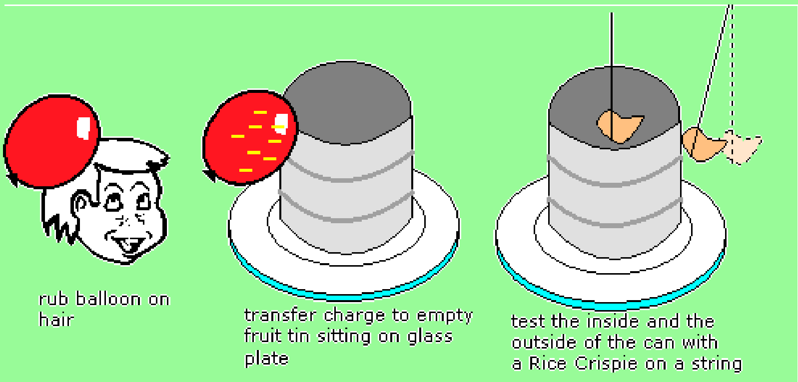


Excess electrons are all over the surface of a 3-dimensional object as shown below. **Note: the region of highest density charge is on the end of greatest curvature.**



There **is no excess charge** inside the conductor**.** **All excess charge is on the surface!**

Seeing is believing. You may have some success by trying the story as told in the series of pictures below. (Caution: why is that you should not touch the can as you go through the charging process?)

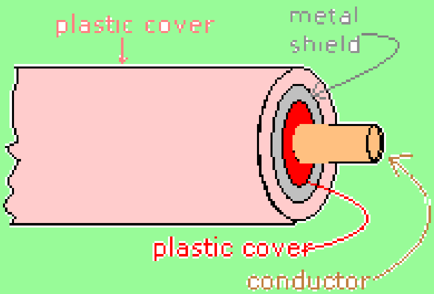


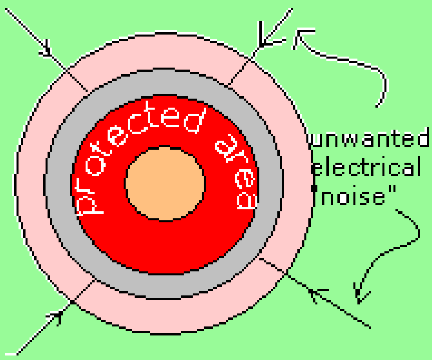
19th century

- Physicist Michael Faraday discovered that all **excess** charge will be found on the outside of a conductor.
- Experiment: He created a room within a room (a box within a box) and covered the outside of the inner room with metal foil. When the walls of the outer room were charged up, sparks were seen to jump between the walls of the two rooms, but Faraday, sitting in the inner room was protected from any shocking experience. This is called Faraday's Cage.
- see http://www.glenbrook.k12.il.us/gbssci/phys/Class/estatics/u8l4d.html

Application of Faraday`s Experiment - Coaxial Cable

Coaxial cable is used to deliver electrical signals to sensitive electrical equipment (e.g., computers, cable TV, recording equipment) because all excess charge resides on the outside of a conductor. The desired information is carried in a wire that is surrounded by a **metal shield.** If there are unwanted electric fields in the environment, the field lines will end (or start) on the outside surface of the metal shield.



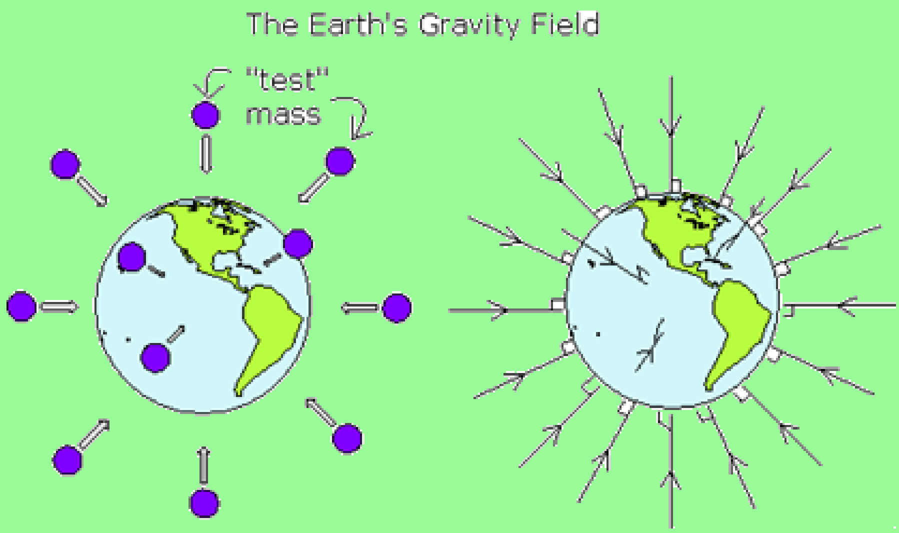


The Concept of a Field

Field – The area around an object (3-D) in which an object exerts some sort of influence.
- gravitational field (last year) – it makes things fall
- electric field (now) – attracts or repels other charges that are brought near it
- magnetic field (learn later in the unit) – affects certain metals and other magnets

Gravitational Field

- If a mass is dropped anywhere on earth, it would always move to the center of the earth.
- A map of the behaviour of the test mass would yield the following diagram.
- Gravity field lines show the path of the mass.

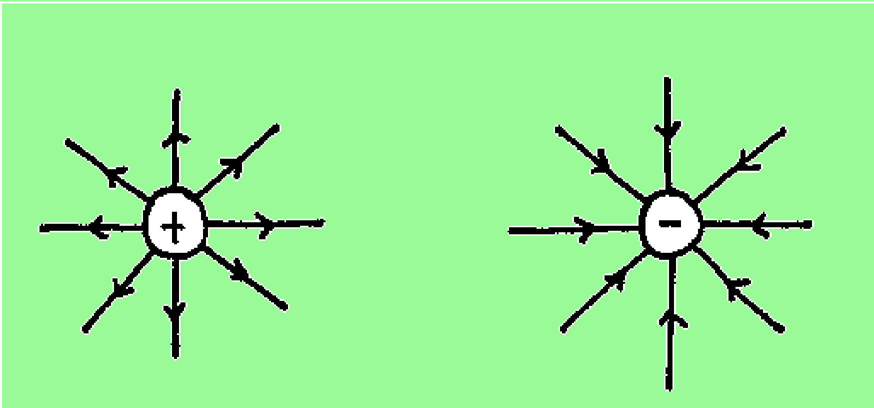


Notice :
- the lines are not in a flat plane. It is a 3-D field.
- the lines meet the surface of the earth at right angles.
- the lines never cross.
- where the field is strongest (near the earth) the lines are closest together.
- the direction of the field is always towards the source (the earth).

Electric Field

- Source of a gravitational field is mass.
- Source of an electric field is a charge. Let the source or main charge be q_m.
- Electric fields are tested with a **test charge**. The test charge is always **POSITIVE.**
- In order to map (draw) electric fields we consider the effect on a test charge brought into the field.
- Electric field lines are in the direction that a **positive test charge moves** when brought near the source or main charge.

The two pictures below show the behaviour of a positive test charge when brought near a main charge that is positive (on the left) and a main charge that is negative (on the right.)



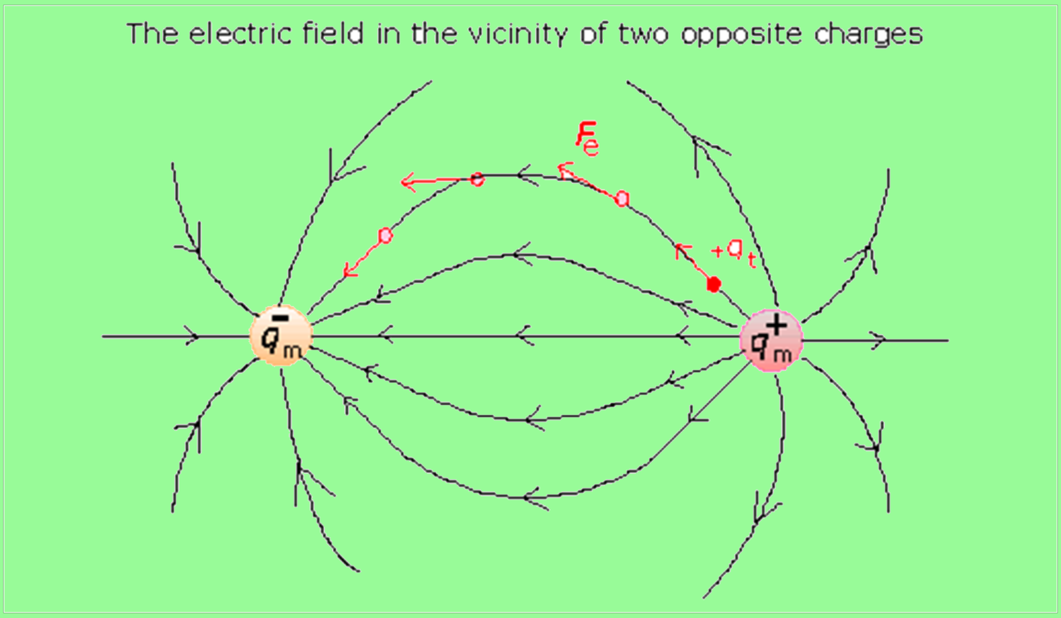
The direction of the arrows indicates the effect on the test charge.

General Statements about electric fields.

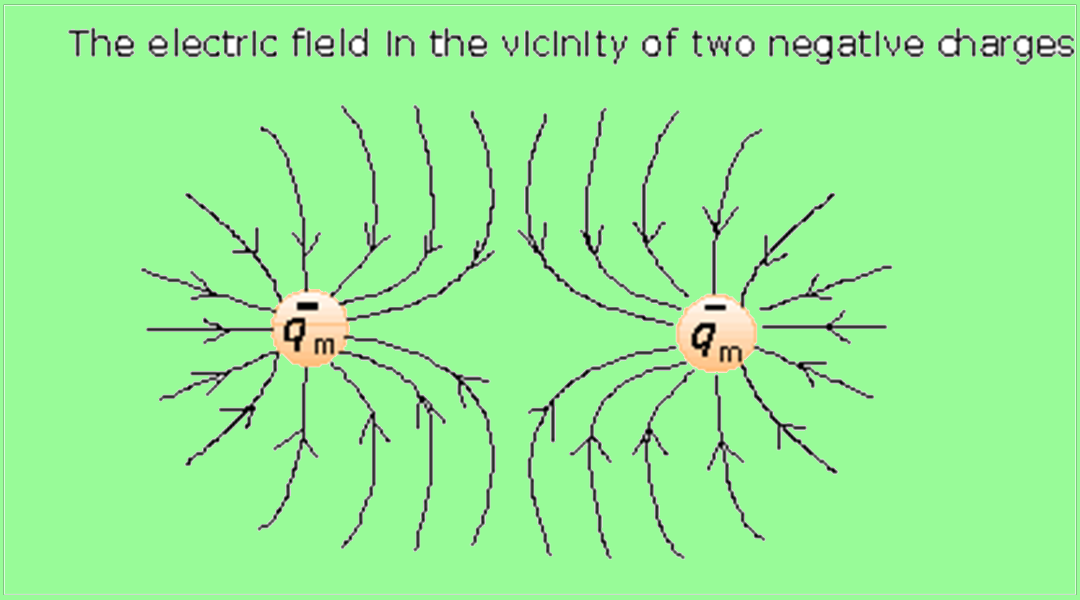
- Direction is determined by a positive test charge. The direction is always towards the main charge when that charge is negative but away from the main charge when that charge is positive. (i.e the lines start on a positive charge and end on a negative charge)
- Lines of force meet the charged object at right angles.
- Lines of force never touch or cross.
- Density of lines indicate field strength (closer together - stronger the field)
- Field is 3- dimensional.

Some Common Electric Field Configurations

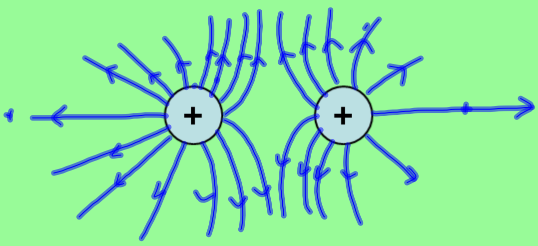
1.



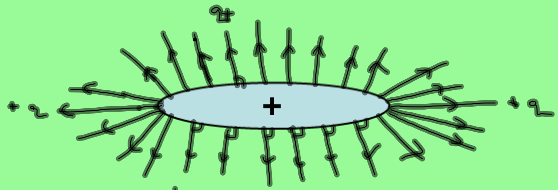
2.



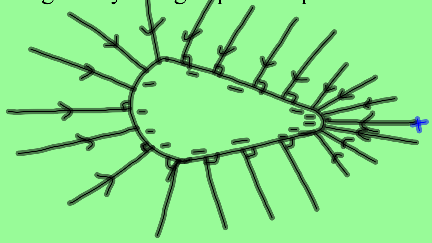
3. The electric field in the vicinity of two positive charges.



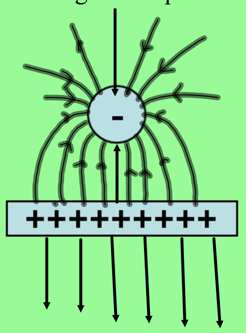
4. A positively charged oval conductor



5. A negatively charged pear shaped conductor

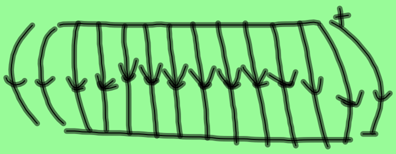


6. A negative charge and a positive plate

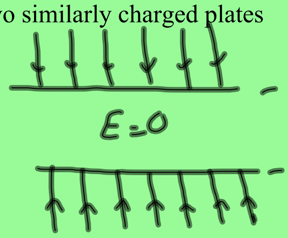


B|W

7. Two oppositely charged plates



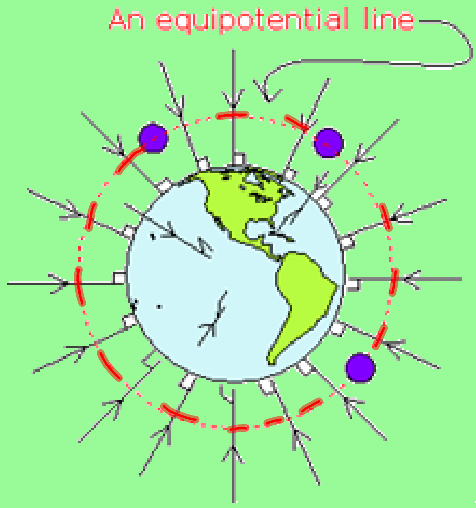
8. Two similarly charged plates



See other configurations on p. 549 of your text.

Equipotential Lines

Consider the earth's **Gravitational Field**:



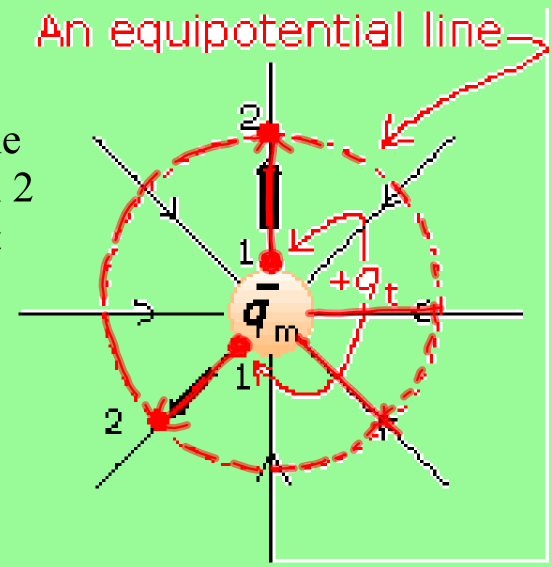
The gravitational potential energy of any mass depends on the height above the earth's surface. If the height doesn't change, then the potential energy doesn't change.

Look at the at the mass in the diagram.

The height is the same for all positions. That means that the potential energy is the same for all the positions shown. In fact, the potential energy is constant anywhere on the dotted circle. The dotted circle is called an equipotential line. Of course you know that the line actually represents a surface (like the peel around an orange.) So, in fact, a better name is equipotential surface.

Electric Fields

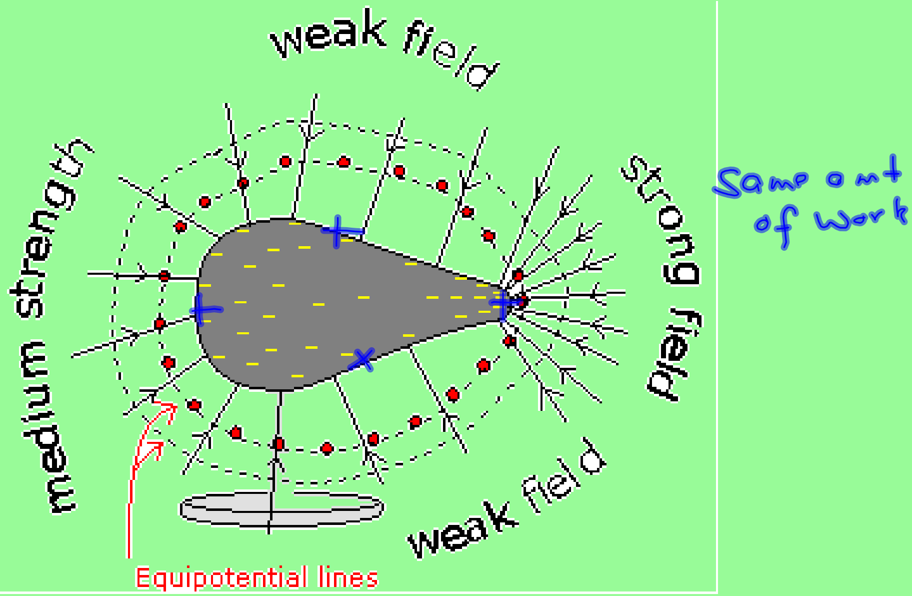
Look at the picture carefully. The test charge q_t is shown at level 1 and at level 2. Because the test charge is **positive**, work is required to move it away from the **negative** main charge. Therefore at level 2 the test charge has potential energy. Not gravitational potential energy, but **electrical potential energy** because the work was done against an electric field, and not against a gravitational field. To move the charge to anywhere on the red circle requires the same amount of work and therefore stores the same amount of electrical potential energy.



A cautionary note

Equipotential lines are not always circular.

Consider the charge distribution around a negatively charged pear shaped conductor. Two equipotential lines are drawn around the conductor.



At the pointy end
- Greatest concentration of charge – strongest field
- A lot of work must be done to move the **positive** test charge **even a small distance** from the negative surface.

On the flat sides
- Charge is scarce, so the field is weak.
- The **same amount of work** will move the charge further from the surface

At the big end
- medium density of charge - medium strength field
- **The same amount of work** will move the test charge further away than it did at the pointy end, but not as far as it did above the flat areas.

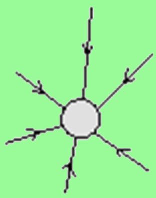
But in all locations the same amount of work was done.
Therefore, the test charges that lie on the dotted line (called an equipotential line) have equal potential energies.

Mapping Electric Fields

Test yourself

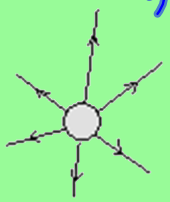
1. Which of the following diagrams properly shows the electrical field around a positively charged sphere?

a



+q

b



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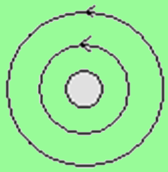
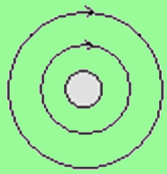
c

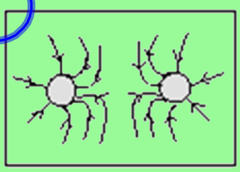


d

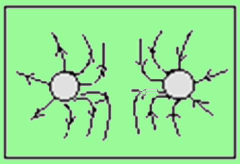


2. Which diagram shows the electric field around two negatively charge spheres?

a



b



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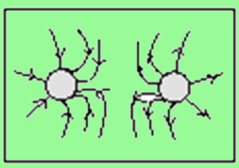
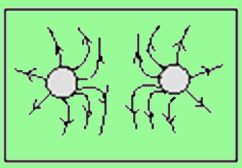
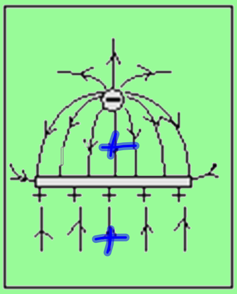


d

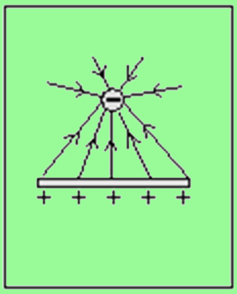


3. A negatively charged ball is brought near a positively charged plate. Which diagram best represents the resulting field?

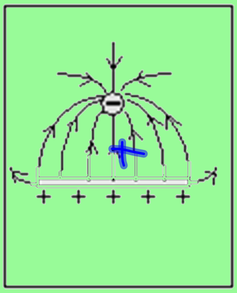
a



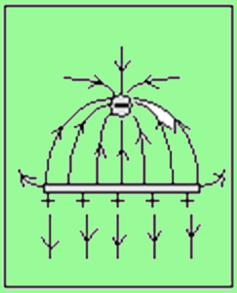
b



c



d

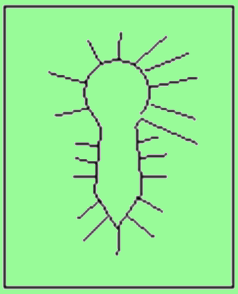


4. A solid block of metal is placed in a uniform electric field. Which statement is correct concerning the electric field in the block's interior?

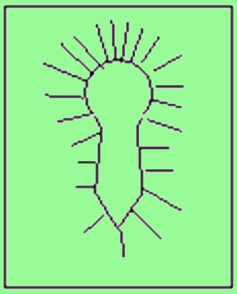
- a) The interior field points in the direction opposite to the exterior field.
- b) The interior field points in the direction at right angles to the exterior field.
- c) The interior field points in the direction that is parallel to the exterior field.
- d) There is no electric field in the blocks interior.

5. Which diagram best illustrates the field around the charged insulated conductor?

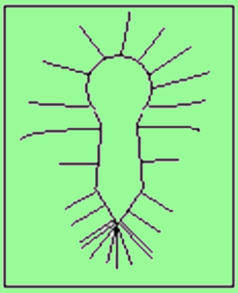
○ a



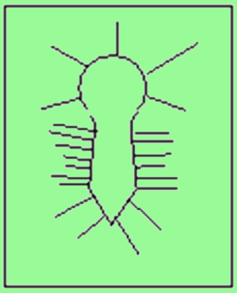
○ b



○ c



○ d



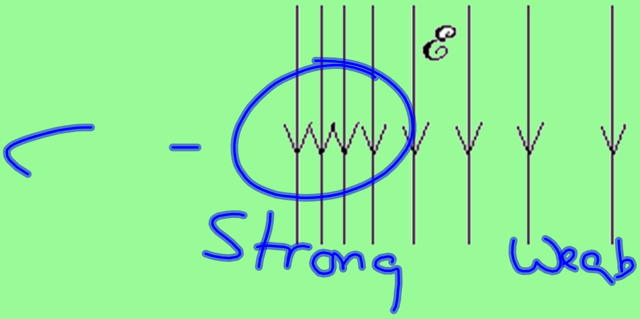
6. Which statement best describes the electric field shown to the right?

○ a) it increases to the right

○ b) it increases going down

○ c) it increase going up

○ d) it increases to the left



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