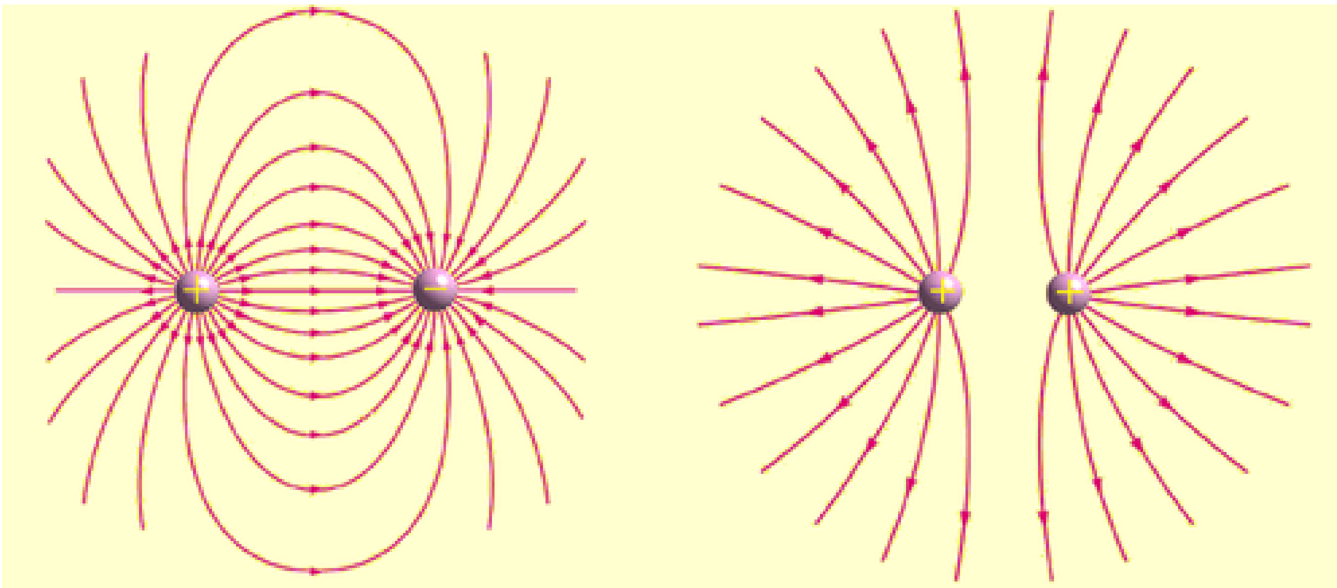
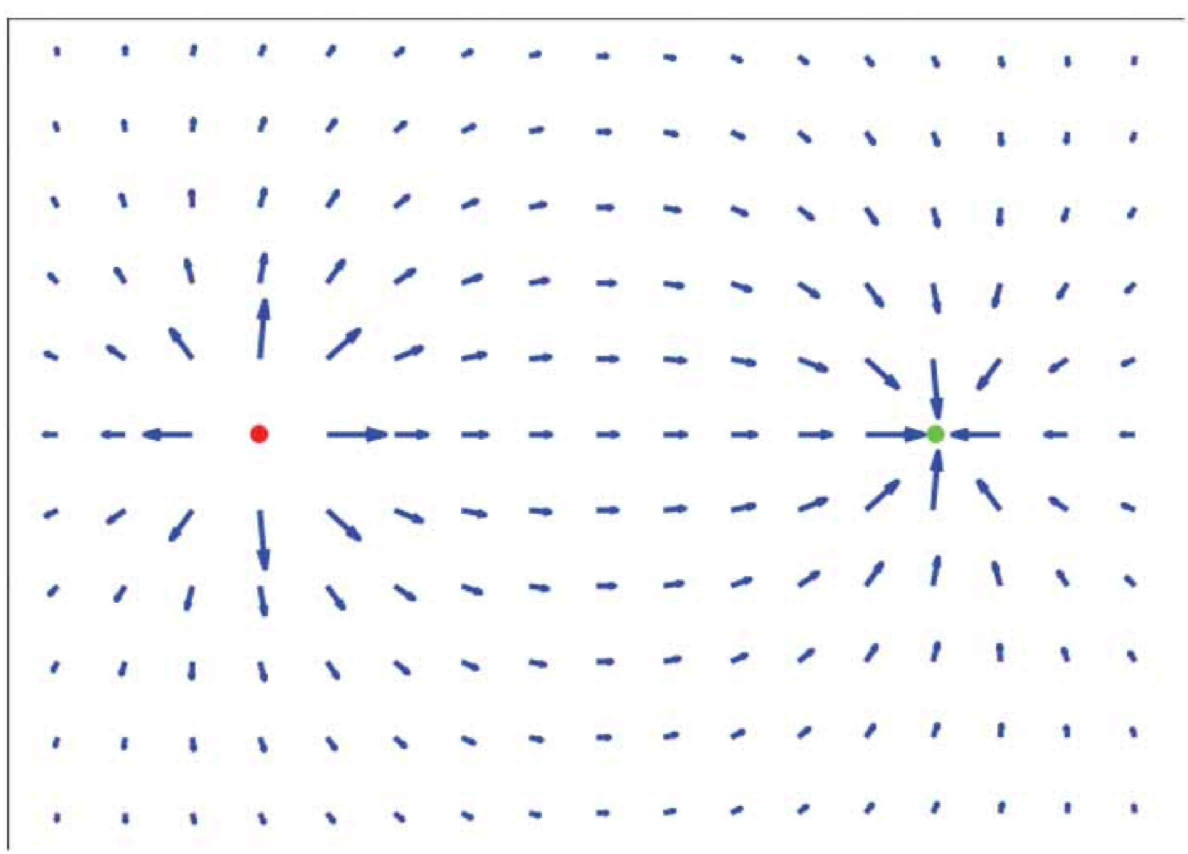
Electric and Gravitational Fields





Warmup Question

Can there be an electric field at a position in space where there is no electric charge?

How could that be possible?

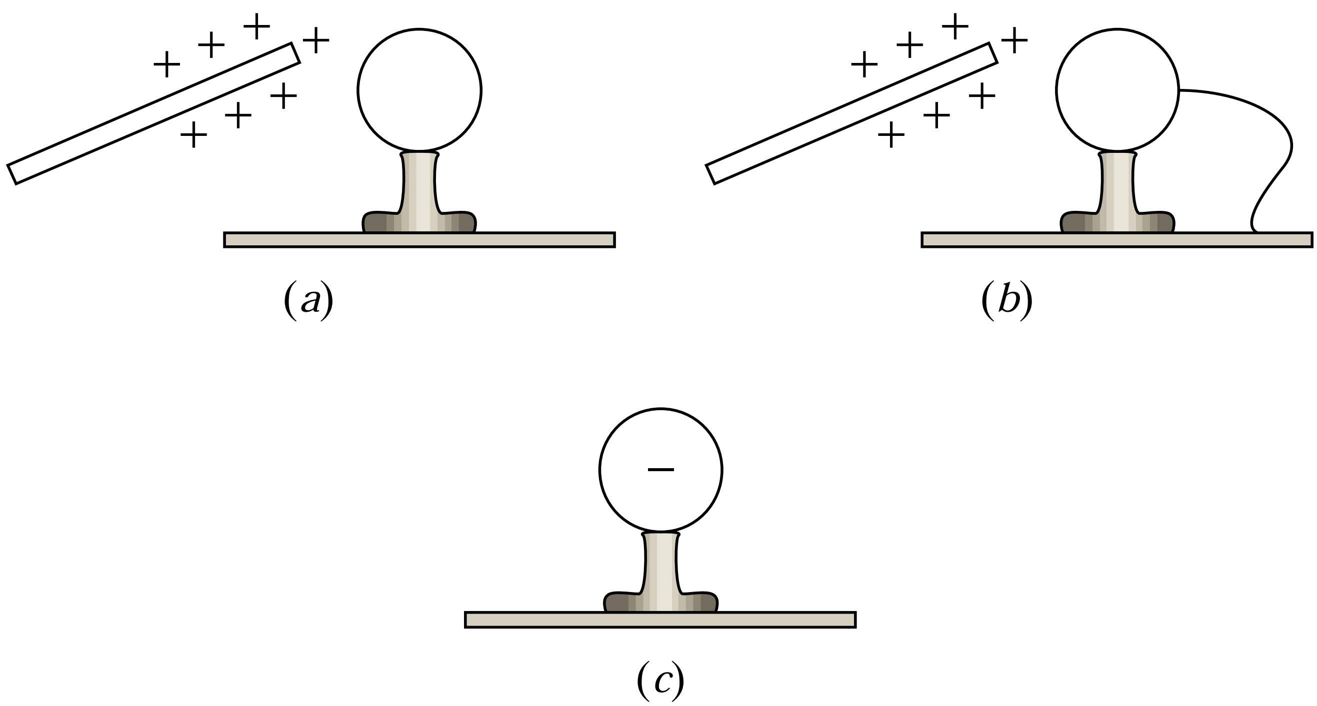
Can there be a charge at a position in space where the field is zero?

Discuss thoroughly.

ANS: Yes, it is possible to have an electric field at a position in space where there is no charge. Electric fields at a point are created by charges *not at* that point. You don't need a charge at a location to have a field there. However, if there is no charge at that point, there will be no electric *force* applied at that point. Electric forces don't exist in empty space; they act on charges.

On the other hand, you can have a charge at a position in space where the field is zero. Consider two equal positive charges. At the point exactly between them, the electric field will be zero (the two field vectors add to zero). If you put a test charge exactly between them, the force on them will be zero. Therefore the field at that point will be zero.

A positively charged object is placed close to a conducting object attached to an insulating glass pedestal (*a*). After the opposite side of the conductor is grounded for a short time interval (*b*), the conductor becomes negatively charged (*c*).



We can conclude that within the conductor

1. positive and negative charges move freely.
2. only negative charges move freely.
3. only positive charges move freely.
4. We can't really conclude anything.

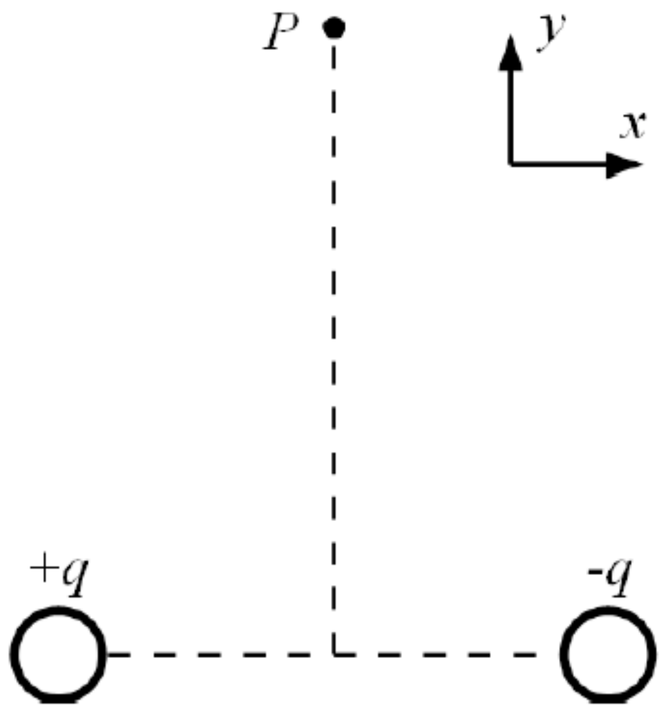
ANS: **4**—We cannot conclude anything about the conductor. Explanations involving moving negative charges and moving positive charges both work.

Here’s the explanation of what is observed if it were the positive charges that move. The positively charged rod repels positive charges in the conducting sphere, leaving a negative charge on the near side. When the wire is connected to the ground, the positive charges on that side of the conductor will readily move even farther from the positive rod, all the way to the ground, leaving the conducting sphere negatively charged. When the wire is removed, a net negative charge remains on the sphere because there are fewer positive than negative charges in it.

Here’s the explanation of what is observed if it were the negative charges that move. The positively charged rod attracts negative charges to the near side, leaving a positive charge on the opposite side. When the wire is connected to the ground, more negative charges will be attracted to the positive charge on that far side and be drawn into the sphere, leaving the sphere negatively charged. When the wire is removed, a net negative charge remains on the sphere because there are more negative than positive charges in it.

In reality, the second explanation is correct, but you cannot conclude that from experiments like this. It was not until the 20th century that we had a good understanding about the structure of matter to determine this.

A pair of equal and opposite charges are placed as illustrated. The electric field at point *P* is

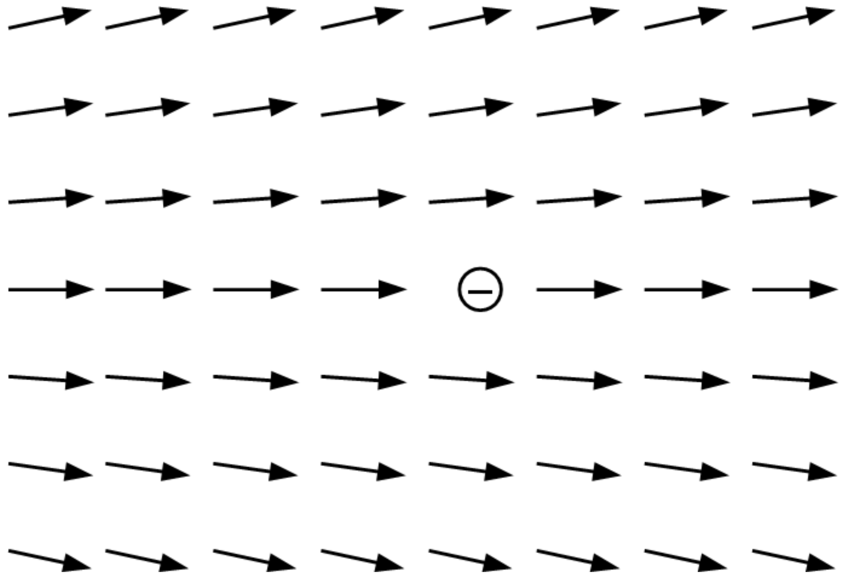


1. along +x
2. along –x
3. along +y
4. along –y
5. depends on the sign of the charge at *P*
6. The electric field at *P* is zero

ANS: **1**—The electric field points in the $+x$ direction.

The two charges are equidistant from P and have charges of equal magnitude, so the electric fields at P due to the two charges are equal in magnitude. The field at P due to the $+q$ charge points up and to the right, away from $+q$. The field at P due to the $-q$ charge points down and to the right, toward $-q$. By symmetry the vertical components of these vectors are equal in size, but opposite in direction, and add to zero. The horizontal components are equal in magnitude and direction, and add to a larger component to the right (the $+x$ direction).

A negatively charged object is placed in an electric field as shown on the right.



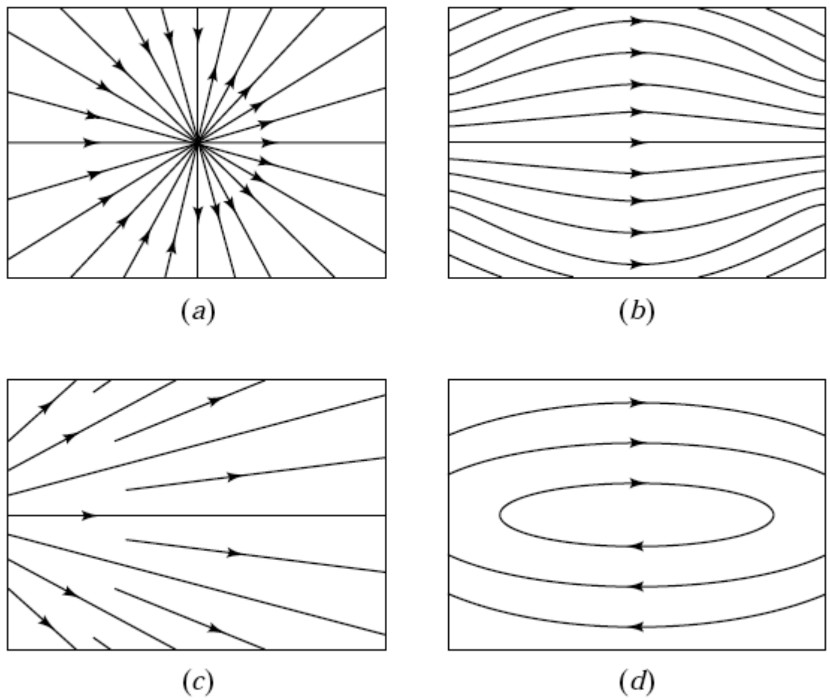
The electric force on the object

1. is to the right
2. is to the left
3. is neither to the left nor to the right
4. depends on whether the field is created by a positively or negatively charged object
5. There is no force on the object at the location shown in the figure.

ANS: **2**—The force on the object is directed to the left.

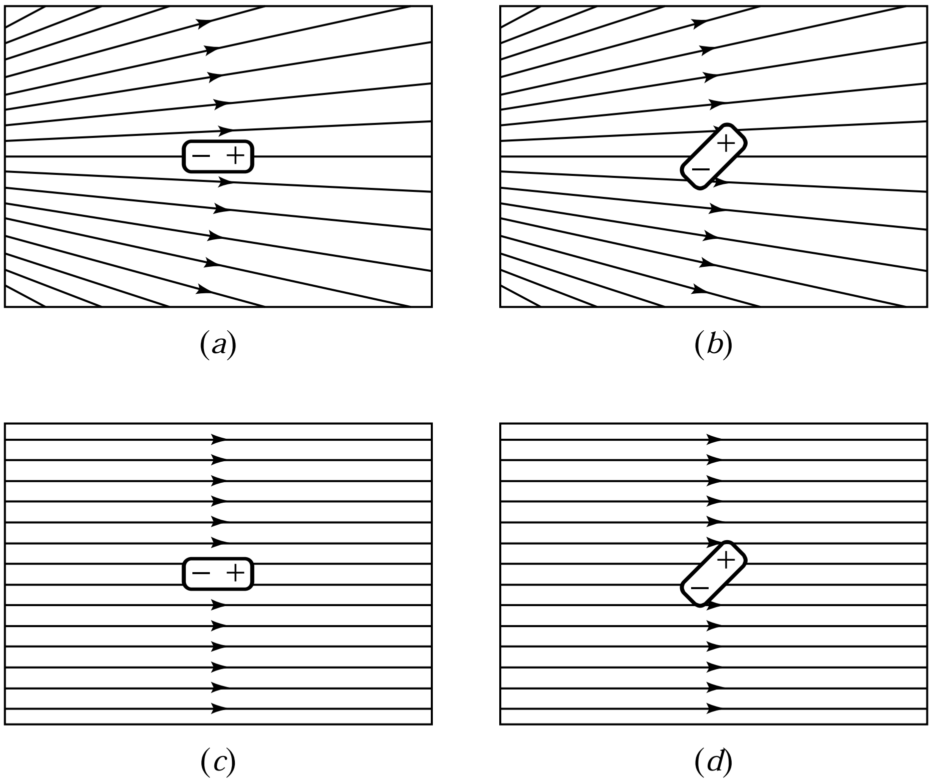
The force on a negative test charge always points opposite the direction of the electric field. (The force on a positive test charge points in the direction of the electric field.)

Consider the four field patterns shown. Assuming there are no charges in the regions shown, which of the patterns represent(s) a possible electrostatic field:



1. (a)
2. (b)
3. (b) and (d)
4. (a) and (c)
5. (b) and (c)
6. some other combination
7. None of the above

An electrically neutral dipole (composed of two equal charges of opposite sign) is placed in an external field. In which situation(s) is the net force on the dipole zero?



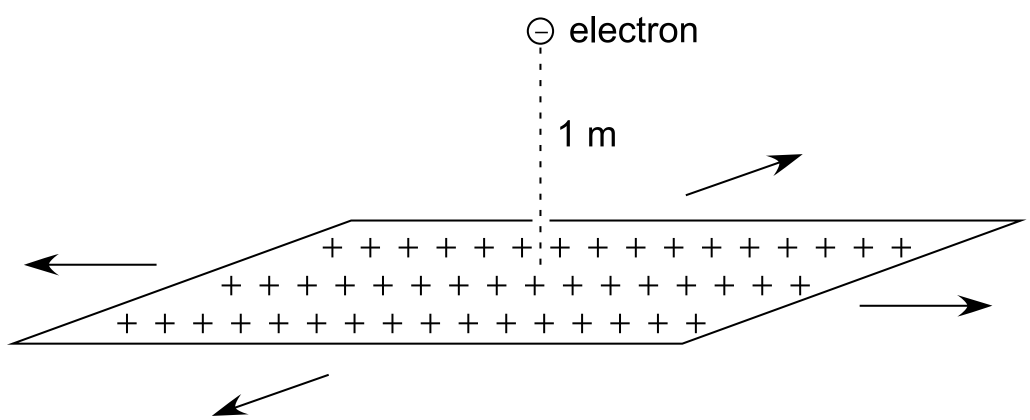
1. (a)
2. (c)
3. (b) and (d)
4. (a) and (c)
5. (c) and (d)
6. some other combination
7. none of the above

ANS: **5**—The net force on the dipole is zero in cases (c) and (d).

In these cases, the field is uniform in magnitude and direction. Therefore, the field at the − charge of the dipole is equal to the field at the + charge of the dipole. Since the two charges that make up a dipole are equal in magnitude, the two forces will be equal in magnitude, but opposite in direction and will add to zero. In cases (a) and (b), the field is weaker at the + charge than it is in at the − charge (the field lines are spaced farther apart). Therefore, the leftward-directed force on the − charge will be greater than the rightward-directed force on the + charge, so the net force in both cases will be to the left.

Note that in cases (b) and (d), there will be a net torque on the dipoles that will tend to cause them to re-orient themselves into the configurations of (a) and (c), but that is not the point of the question.

Consider a flat two-dimensional plane of infinite extent that is covered with a uniform distribution of electric charge. At a position 1 meter above this charged plane an electron feels a force of 1 newton. Based on the properties of electric field lines, what force would be felt if the electron were moved to a position 2 meters above the plane?



1. 1/4 N
2. 1/3 N
3. 1/2 N
4. 1 N
5. 2 N
6. 3 N
7. impossible to determine with the information given

Warmup Question

An old fashioned (non-flat screen!) television tube works by accelerating electrons ($m = 9.11 \times 10^{-31}$ kg, $q = 1.6 \times 10^{-19}$ C) using an electric field and firing them toward a phosphorescent screen. They actually hit the screen moving at about one quarter of the speed of light! (The speed of light is 3×10^{8} m/s). Calculate (using reasonable estimates for the input quantities) the electric field, assuming it provides a uniform acceleration over the entire distance.

ANS: The electrons accelerate from rest to a speed of around $10^8\,\mathrm{m/s}$ over a distance of around $d = 0.5\,\mathrm{m}$. Then the acceleration of the charge will be

$$a = \frac{v^2}{2d} = \frac{(10^8\,\mathrm{m/s})^2}{1\,\mathrm{m}} = 10^{16}\,\mathrm{m/s^2}\,.$$

This will result in a force of around $(10^{-30}\,\mathrm{kg})(10^{16}\,\mathrm{m/s^2}) = 10^{-14}\,\mathrm{N}$. This force, applied to a charge of around $10^{-19}\,\mathrm{C}$, will be due to an electric field of around $(10^{-14}\,\mathrm{N})/(10^{-19}\,\mathrm{C}) = 10^5\,\mathrm{N/C}$.

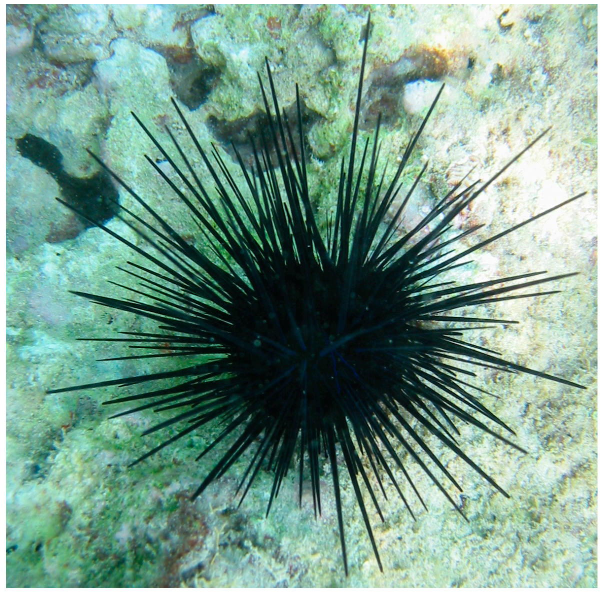
Warmup Question

The electric field from a lone charge looks most like a

1. Sea squirt
2. Sea urchin
3. Sea horse
4. Sea gull

ANS: **2**—The electric field from a lone point charge looks like a sea urchin, a spikey aquatic animal.

Here's a sea urchin:



Here's the electric field from a lone charge: