The above vector field is created by:

1. Two sources (equal strength)
2. Two sources (top stronger)
3. Two sources (bottom stronger)
4. Source & Sink (equal strength)
5. Source & Sink (top stronger)
6. Source & Sink (bottom stronger)
7. I don’t know
(3) Two sources, bottom stronger

Both sources because lines leaving one don’t enter the other.
Bottom is stronger because it “pushes” further
The force between the two charges is:
1) Attractive
2) Repulsive
3) Can’t tell without more information
(2) Repulsive

One way to tell is to notice that they both must be sources (or sinks). Hence, as like particles repel, the force is repulsive.

You can also see this as tension in the field lines
Here there is an initial downward flow.

1. The point is a source
2. The point is a sink
3. I don’t know
(1) Source

It’s a source, because otherwise the downward flow would flow right into it.

NOTE: If the background were upward, then it would be just flowing right into it, so it would be a sink.
The “grass seeds” field plot above is a representation of the vector field:

1. \( \vec{F}(x, y) = x^2 \hat{i} + y^2 \hat{j} \)
2. \( \vec{F}(x, y) = y^2 \hat{i} + x^2 \hat{j} \)
3. \( \vec{F}(x, y) = x \hat{i} + y \hat{j} \)
4. \( \vec{F}(x, y) = -y \hat{i} + x \hat{j} \)
5. NOT SURE
Answer: 3. \( \vec{F}(x, y) = x \hat{i} + y \hat{j} \)

At any point in space the vector function given above points away from the origin, so 3 is the correct answer.
The “grass seeds” field plot above is a representation of the vector field:

1. \( \vec{F}(x, y) = x^2 \hat{i} + y^2 \hat{j} \)
2. \( \vec{F}(x, y) = y^2 \hat{i} + x^2 \hat{j} \)
3. \( \vec{F}(x, y) = x \hat{i} + y \hat{j} \)
4. \( \vec{F}(x, y) = -y \hat{i} + x \hat{j} \)
5. **NOT SURE**
Answer: 4.  \( \vec{F}(x, y) = -y \hat{i} + x \hat{j} \)
Along the positive x-axis the grass seed textures are vertical. This means \( \vec{F} \) has only a y component along this axis, which means either answer 2 or 4. The answer must be 4 because 2 will give a positive x-component on the positive y-axis, and that component must be -.
Two opposite charges are placed on a line as shown below. The charge on the right is three times larger than the charge on the left. Other than at infinity, where is the electric field zero?

1. Between the two charges
2. To the right of the charge on the right
3. To the left of the charge on the left
4. The electric field is nowhere zero
(3) Zero is left of $q_L$

In between the charges the field is always from source to sink.

To the right of $q_R$, the field is dominated by $q_R$ (bigger & closer)

On the left, because the charge on the left is weaker, its “push” to its left will somewhere be balanced by $q_R$’s “pull” to the right
E-Field of Two Equal Charges

Electric field at point P is:

1. \( \vec{E} = \frac{2k_e q s}{\left( s^2 + \frac{d^2}{4} \right)^{3/2}} \hat{j} \)

2. \( \vec{E} = -\frac{2k_e q d}{\left( s^2 + \frac{d^2}{4} \right)^{3/2}} \hat{i} \)

3. \( \vec{E} = \frac{2k_e q d}{\left( s^2 + \frac{d^2}{4} \right)^{3/2}} \hat{j} \)

4. \( \vec{E} = -\frac{2k_e q s}{\left( s^2 + \frac{d^2}{4} \right)^{3/2}} \hat{i} \)

5. Don’t Know
E-Field of Two Equal Charges

1. \[
\vec{E} = \frac{2k_e q s}{\left[s^2 + \frac{d^2}{4}\right]^{3/2}} \hat{j}
\]

There are several ways to see this. For example, consider \(d \to 0\). Then,

\[
\vec{E} \to k_e \frac{2q}{s^2} \hat{j}
\]

which is what we want (sitting above a point charge with charge 2q)
Negative Charge

Place a negative charge in an electric field. It will move from
1. higher to lower electric potential and from lower to higher potential energy
2. higher to lower electric potential and from higher to lower potential energy
3. lower to higher electric potential and from lower to higher potential energy
4. lower to higher electric potential and from higher to lower potential energy
Negative Charge

(4) From lower to higher potential and higher to lower potential energy

Objects always move to reduce their potential energy. Negative charges do this by moving towards a higher potential:

\[ U = qV \]
Potential and Energy

Which is true?
I. It takes positive work to bring like charges together.
II. Electric field lines always point in the direction of decreasing electric potential.
III. If a negative charge moves in the direction of the electric field, its electric potential energy decreases.

1. II only.
2. II and III only.
3. I, II and III.
4. I and II only.
5. I only.
Potential and Energy

(4) I and II Only

I. It takes positive work to bring like charges together.  TRUE

II. Electric field lines always point in the direction of decreasing electric potential.  TRUE

III. If a negative charge moves in the direction of the electric field, its electric potential energy decreases. FALSE – potential decreases so potential energy increases \((U = qV)\)
Two Point Charges

The work done in moving a positive test charge from infinity to the point P midway between two charges of magnitude +q and –q:

1. is positive.
2. is negative.
3. is zero.
4. can not be determined since not enough information is given.
5. I don’t know
Two Point Charges

(3) Work from $\infty$ to $P$ is zero

The potential at $\infty$ is zero. The potential at $P$ is zero because equal and opposite potentials are superimposed from the two point charges (remember: $V$ is a scalar, not a vector)
The graph above shows a potential $V$ as a function of $x$. The magnitude of the electric field for $x > 0$ is

1. larger than that for $x < 0$
2. smaller than that for $x < 0$
3. equal to that for $x < 0$
4. I don’t know
(2) The electric field for \( x > 0 \) is smaller than that for the electric field for \( x < 0 \) because the slope of the potential is smaller in the region \( x > 0 \) as compared to \( x < 0 \). **Translation:** The hill is steeper on the left than on the right.
The graph above shows a potential V as a function of x. Which is true?

1. $E_x > 0$ is $> 0$ and $E_x < 0$ is $> 0$
2. $E_x > 0$ is $> 0$ and $E_x < 0$ is $< 0$
3. $E_x > 0$ is $< 0$ and $E_x < 0$ is $< 0$
4. $E_x > 0$ is $< 0$ and $E_x < 0$ is $> 0$
5. I don’t know
(2) The electric field for $x > 0$ is in the positive $x$-direction, because as $x$ decreases for $x > 0$ the potential increases, which can only happen if the electric field opposes movement to smaller $x$ for $x > 0$. **Translation:** “Downhill” is to the left on the left and to the right on the right.
E Field from Slab

A positively charged, semi-infinite flat slab has thickness D.

The z-axis is perpendicular to the sheet, with center at \( z = 0 \).

At the plane’s center \( (z = 0) \), \( E \)
1. points in the positive z-direction
2. points in the negative z-direction
3. is zero
4. I don’t know
E Field from Slab

(3) At the center of the slab the electric field is 0.

\[ \rho \quad D \quad z = 0 \]

Symmetry tell us this – the amount of charge above and below the center of the plane is equal hence the fields cancel.

Another way of saying this is that since you don’t know which way the field would point it must be 0.
E Field from Slab

A positively charged, semi-infinite flat slab has thickness D. The z-axis is perpendicular to the sheet, with its center at $z = 0$.

A distance $z$ from its central plane,
1. $E$ is constant
2. $E \propto \frac{1}{z^2}$
3. $E \propto \frac{1}{z}$
4. $E \propto z$
5. I don't know
E Field from Slab

(4) E is proportional to z inside the slab.

As you move away from the center, an imbalance is generated in the amount of charge below you and the amount above you. This imbalance grows linearly with z, and is what leads to the E field that you see.

Once outside the slab, the imbalance stops changing so the field is constant.
Torque On A Dipole

An dipole is placed in an external field. In which situation(s) is the net torque on the dipole zero?

1. (a)
2. (c)
3. (b) and (d)
4. (a) and (c)
5. (c) and (d)
6. Don’t know
Torque On A Dipole

A dipole is placed in an external field. In which situation(s) is the net torque on the dipole zero?

**Answer:** 4. (a) and (c). An electric dipole in an electric field experiences a net torque only if it is at an angle to the direction of the external electric field. If it is parallel or anti-parallel to the field it feels no net torque.
Force On A Dipole
An dipole 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. Don’t know
Force On A Dipole
An dipole is placed in an external field. In which situation(s) is the net force on the dipole zero?

Answer: 5. (c) and (d). An electric dipole in a **uniform** electric field experiences zero net force, and the field is uniform in (c) and (d).
Hollow Conductors

A point charge $+Q$ is placed at the center of the conductors. The induced charges are:

1. $Q(I1) = Q(I2) = -Q$;
   $Q(O1) = Q(O2) = +Q$

2. $Q(I1) = Q(I2) = +Q$;
   $Q(O1) = Q(O2) = -Q$

3. $Q(I1) = -Q$; $Q(O1) = +Q$
   $Q(I2) = Q(O2) = 0$

4. $Q(I1) = -Q$; $Q(O2) = +Q$
   $Q(O1) = Q(I2) = 0$
Hollow Conductors

(1) The inner faces are negative, the outer faces are positive.

Looking in from each conductor, the total charge must be zero (this gives the inner surfaces as $-Q$). But the conductors must remain neutral (which makes the outer surfaces have induced charge $+Q$).
Hollow Conductors

A point charge \(+Q\) is placed at the center of the conductors. The potential at \(O_1\) is:

1. Higher than at \(I_1\)
2. Lower than at \(I_1\)
3. The same as at \(I_1\)
Hollow Conductors

(3) O1 and I1 are at the same potential

A conductor is an equipotential surface. O1 and I1 are on the same conductor, hence at the same potential.
A point charge $+Q$ is placed at the center of the conductors. The potential at O2 is:

1. Higher than at I1
2. Lower than at I1
3. The same as at I1
Hollow Conductors

(2) $O_2$ is lower than $I_1$

As you move away from the positive point charge at the center, the potential decreases.
Hollow Conductors

A point charge $+Q$ is placed at the center of the conductors. If a wire is used to connect the two conductors, then positive charge will flow

1. From the inner to the outer conductor
2. From the outer to the inner conductor
3. Not at all
Hollow Conductors

(1) Positive charge flows outward

Positive charges always flow “downhill” – from high to low potential. Since the inner conductor is at a higher potential the charges will flow from the inner to the outer conductor.
Hollow Conductors

A point charge $+Q$ is placed at the center of the conductors, and a wire connects the two. If the wire and then the charge are removed, the potential at inner conductor is

1. Higher than at the outer conductor
2. Lower than at the outer conductor
3. The same as at the outer conductor
Hollow Conductors

(2) The inner conductor is now at a lower potential

With the positive charge in the center and a wire connecting the two conductors, positive charge will flow outwards, leaving a net negative charge on the inner conductor when the wire is removed.

Thus when the $+Q$ is removed the inner sphere is at a lower potential.
Changing C Dimensions

A parallel-plate capacitor has plates with equal and opposite charges, separated by a distance $d$. The capacitor is not connected to a battery.

Suppose the plates are pulled apart until separated by a distance $D > d$. Does the potential difference between the plates:

1. Increase
2. Decrease
3. Stay the same
Changing C Dimensions

(1) Potential Increases

The electric field doesn’t change when you change the distance between the plates, so:

\[ V = E \cdot d \]

As \( d \) increases, \( V \) increases.
Changing C Dimensions

A parallel-plate capacitor, disconnected from a battery, has plates with equal and opposite charges, separated by a distance $d$. Suppose the plates are pulled apart until separated by a distance $D > d$. How does the final electrostatic energy stored in the capacitor compare to the initial energy?

1. The final stored energy is smaller
2. The final stored energy is larger
3. Stored energy does not change.
Changing C Dimensions

(2) The stored energy increases

As you pull apart the capacitor plates you are increasing the amount of space in which the E field is non-zero and hence increase the stored energy. Where does the extra energy come from? From the work you do pulling the plates apart.
Dielectric in a Capacitor

A parallel plate capacitor is charged to a total charge $Q$ and the battery removed. A slab of material with dielectric constant $\kappa$ is inserted between the plates. The charge stored in the capacitor

1. Increases
2. Decreases
3. Stays the Same
Dielectric in a Capacitor

(3) The charge is unchanged

Since the capacitor is disconnected from a battery there is no way for the amount of charge on it to change.
Dielectric in a Capacitor

A parallel plate capacitor is charged to a total charge Q and the battery removed. A slab of material with dielectric constant $\kappa$ in inserted between the plates. The energy stored in the capacitor

1. Increases
2. Decreases
3. Stays the Same
Dielectric in a Capacitor

(2) The energy stored decreases

The dielectric reduces the electric field and hence reduces the amount of energy stored in the field.
Dielectric in a Capacitor

A parallel plate capacitor is charged to a total charge \( Q \) and the battery removed. A slab of material with dielectric constant \( \kappa \) is inserted between the plates. The force on the dielectric

1. pulls in the dielectric
2. pushes out the dielectric
3. is zero
Dielectric in a Capacitor

(1) The dielectric is pulled into the capacitor

We just saw that the energy is reduced by the introduction of a dielectric. Since systems want to reduce their energy, the dielectric will be sucked into the capacitor.

Alternatively, since opposing charges are induced on the dielectric surfaces close to the plates, the attraction between these will lead to the attractive force.
Dielectric in a Capacitor

A parallel plate capacitor is connected to a battery and charged to a total charge Q. A slab of material with dielectric constant $\kappa$ in inserted between the plates. The charge stored in the capacitor

1. Increases
2. Decreases
3. Stays the Same
Dielectric in a Capacitor

(1) The stored charge increases

In order to keep the voltage the same, since the capacitance increases the charge stored must also increase \((Q = CV)\)

More intuitively, since opposing charges are induced on the dielectric surfaces close to the plates, extra charge will be attracted into the capacitor.
Dielectric in a Capacitor

A parallel plate capacitor is connected to a battery. A slab of material with dielectric constant $\kappa$ in partially inserted between the plates. The electric field in the dielectric

1. is larger than the E field to the left
2. is smaller than the E field to the left
3. is the same as the E field to the left
Dielectric in a Capacitor

(3) The E field in the dielectric is the same as the E field outside the dielectric

This might seem wrong since dielectrics decrease electric fields. However, the potential difference between the plates is fixed and $V=Ed$, whether going through the dielectric or not. So $E=V/d$ in both regions.

How? Charge will move to the right (by the dielectric) while it is being inserted.