Electric Field

- Take a small positive test charge q_0 at some point in space P.
- Find the force produced on it by all of the other charges in the system.
- Each of those forces proportional to q_0.
- So total force is proportional to q_0.
- Electric field is total force divided by q_0.

$$\vec{\mathbf{E}}_P = \frac{\vec{\mathbf{F}}}{q_0} \quad \vec{\mathbf{F}} = q_0\vec{\mathbf{E}}$$

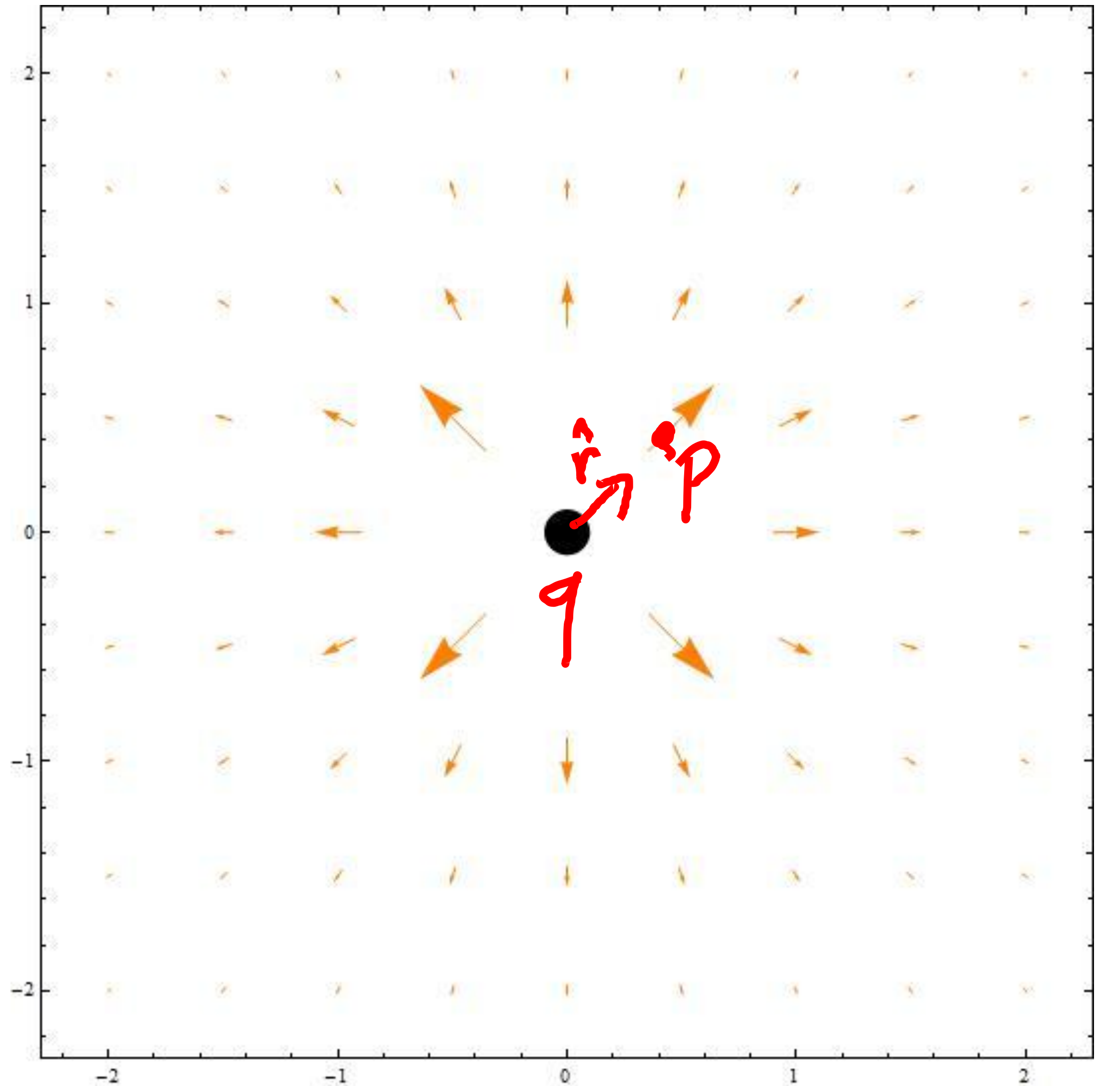
The direction of the electric field at a point is the same as

1) the direction of the force on a neutron placed at that point.
2) the direction of the force on a proton placed at that point.
3) the direction of the force on an electron placed at that point.
4) the direction of the force on a hydrogen molecule placed at that point.
5) None of these is correct.

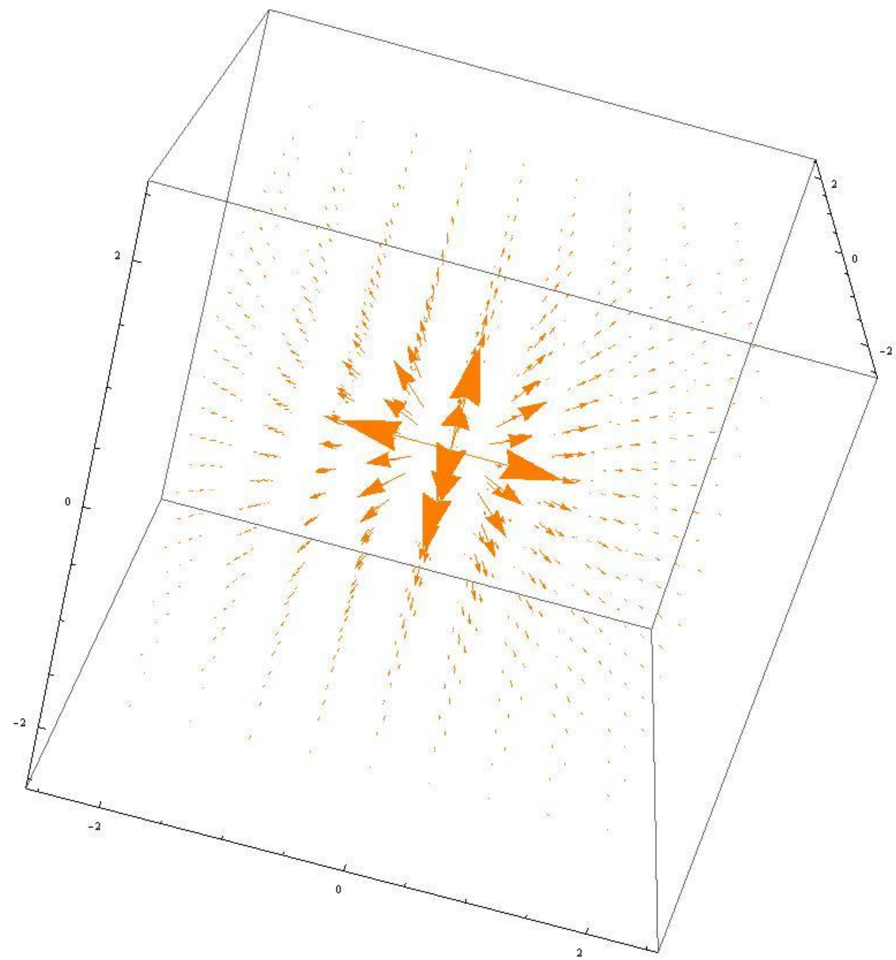
Electric field of single point charge

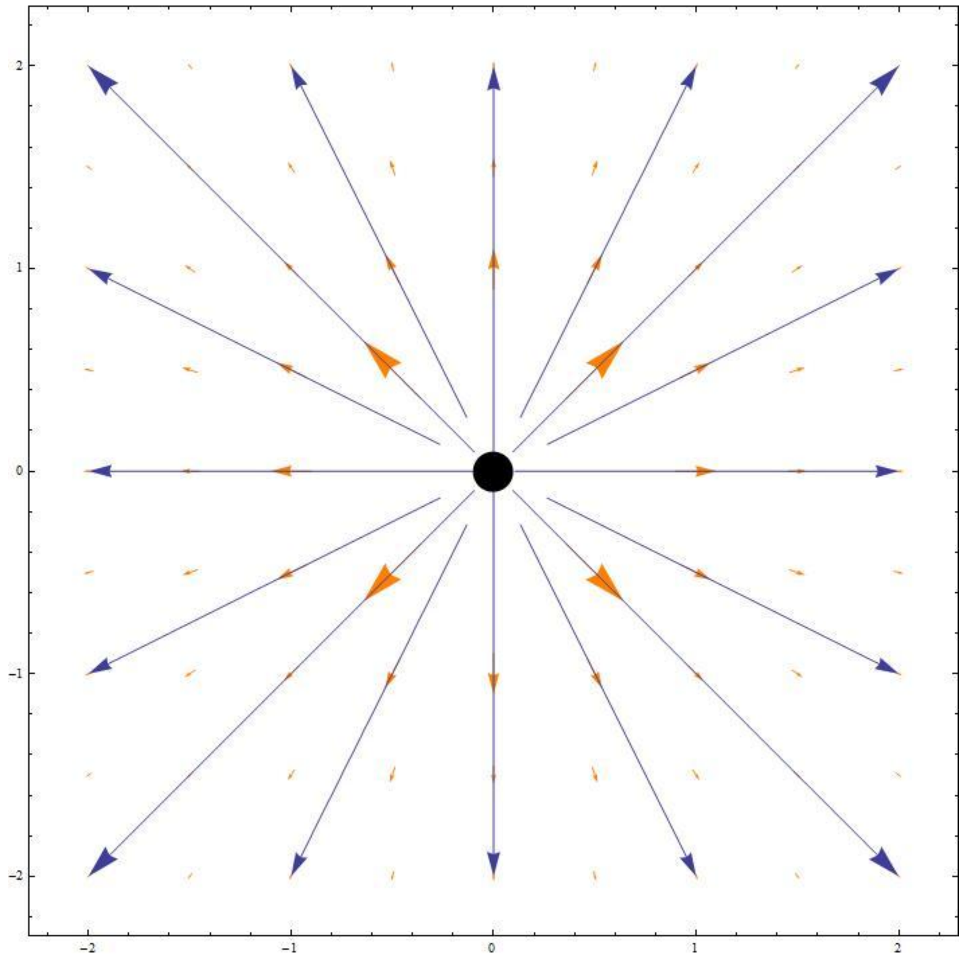
$$\vec{\mathbf{E}}_P = \frac{kq}{r_{q,P}^2}\hat{\mathbf{r}}_{q,P}$$

Electric field of single point charge – 2D view



Electric field of single point charge – 3D view





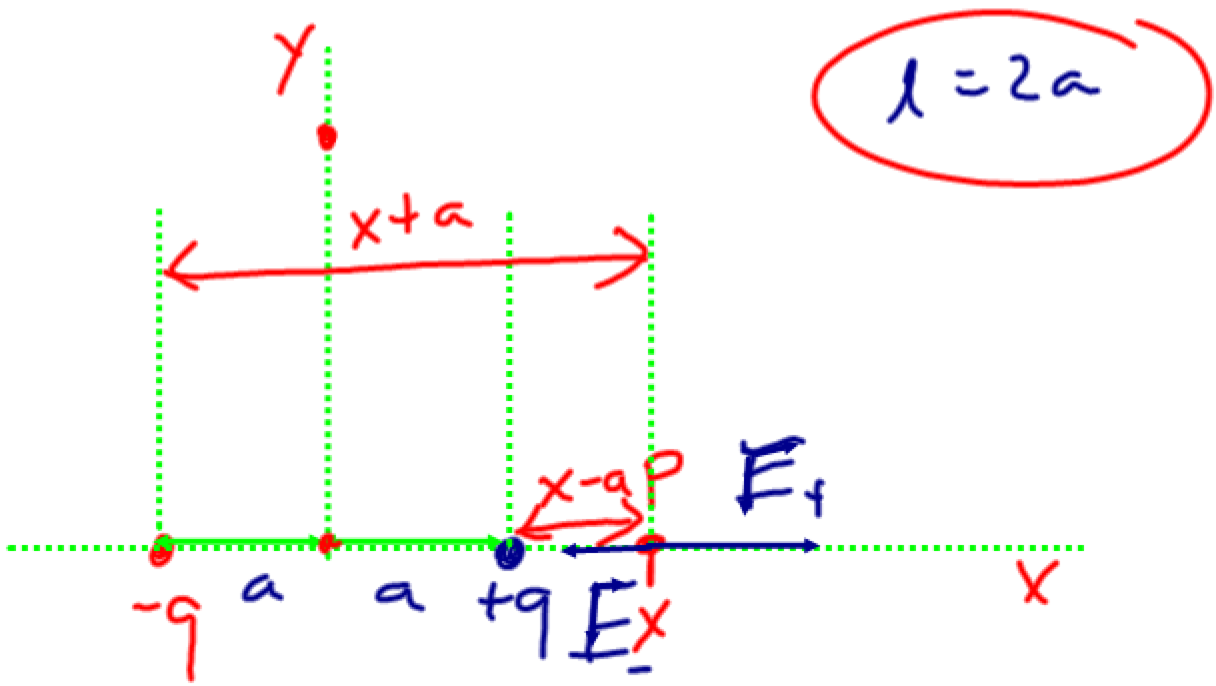
2
1
0
−1
−2
−2
−1
0
1
2

More than one point charge

- Electric fields add like vectors (Principle of Superposition).
- The total electric field at point P is the vector sum of the fields due to each of the individual point charges.

Electric Dipole

- Two equal, but opposite charges a fixed distance apart.



Electric field produced by a dipole

- Along x axis:

$$\vec{\mathbf{E}} = 2kql \frac{x}{\left(x^2 - a^2\right)^2} \hat{\mathbf{i}}$$

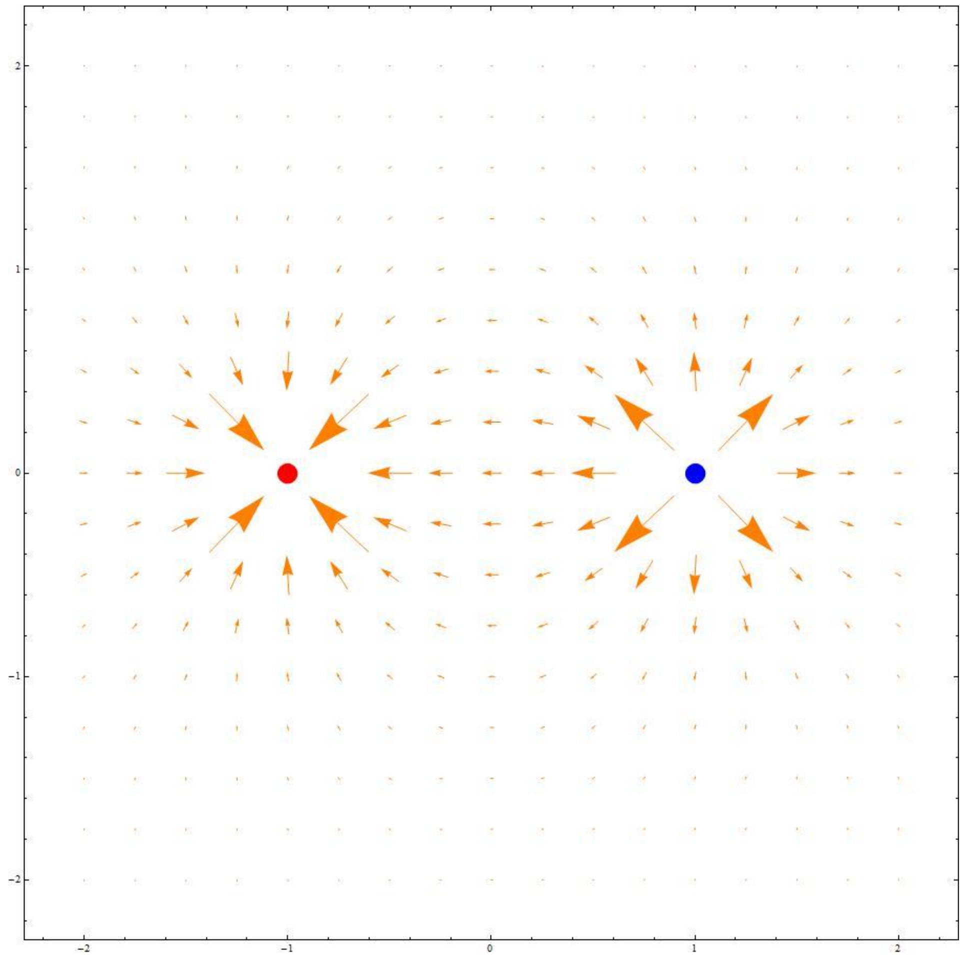
$$\approx 2kql \frac{1}{x^3} \hat{\mathbf{i}} \quad \text{for } x >> a \text{ (or } x << -a\text{)}$$

- Electric “dipole moment”:

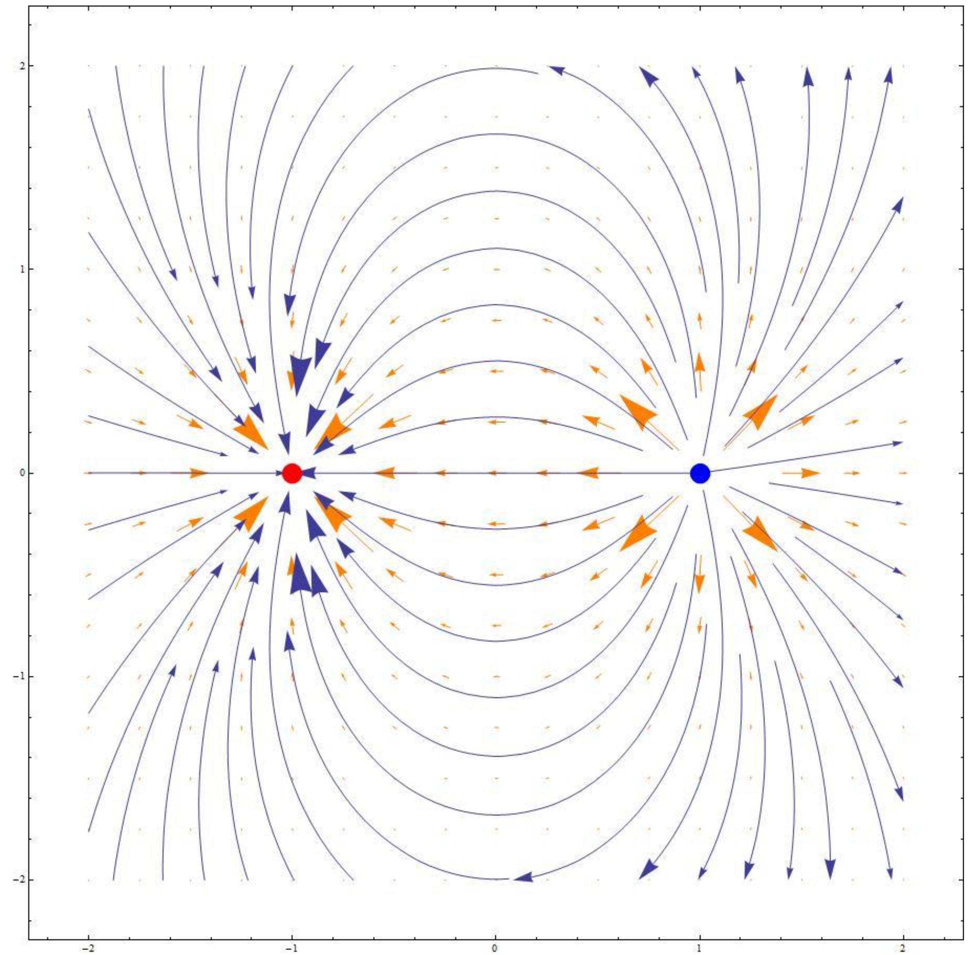
$$p = ql$$

Points in direction – to +.

Dipole electric field – 2D view

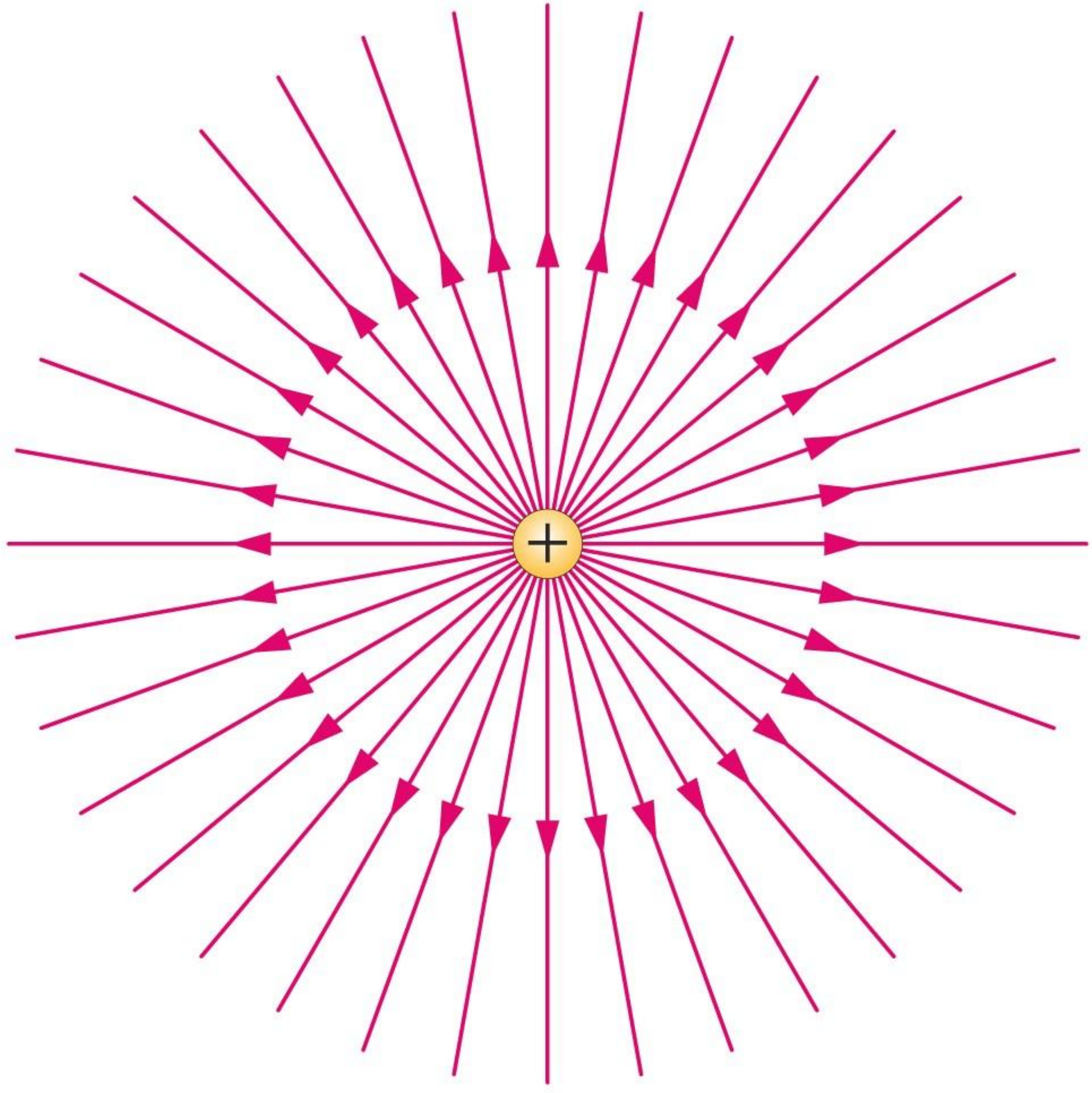


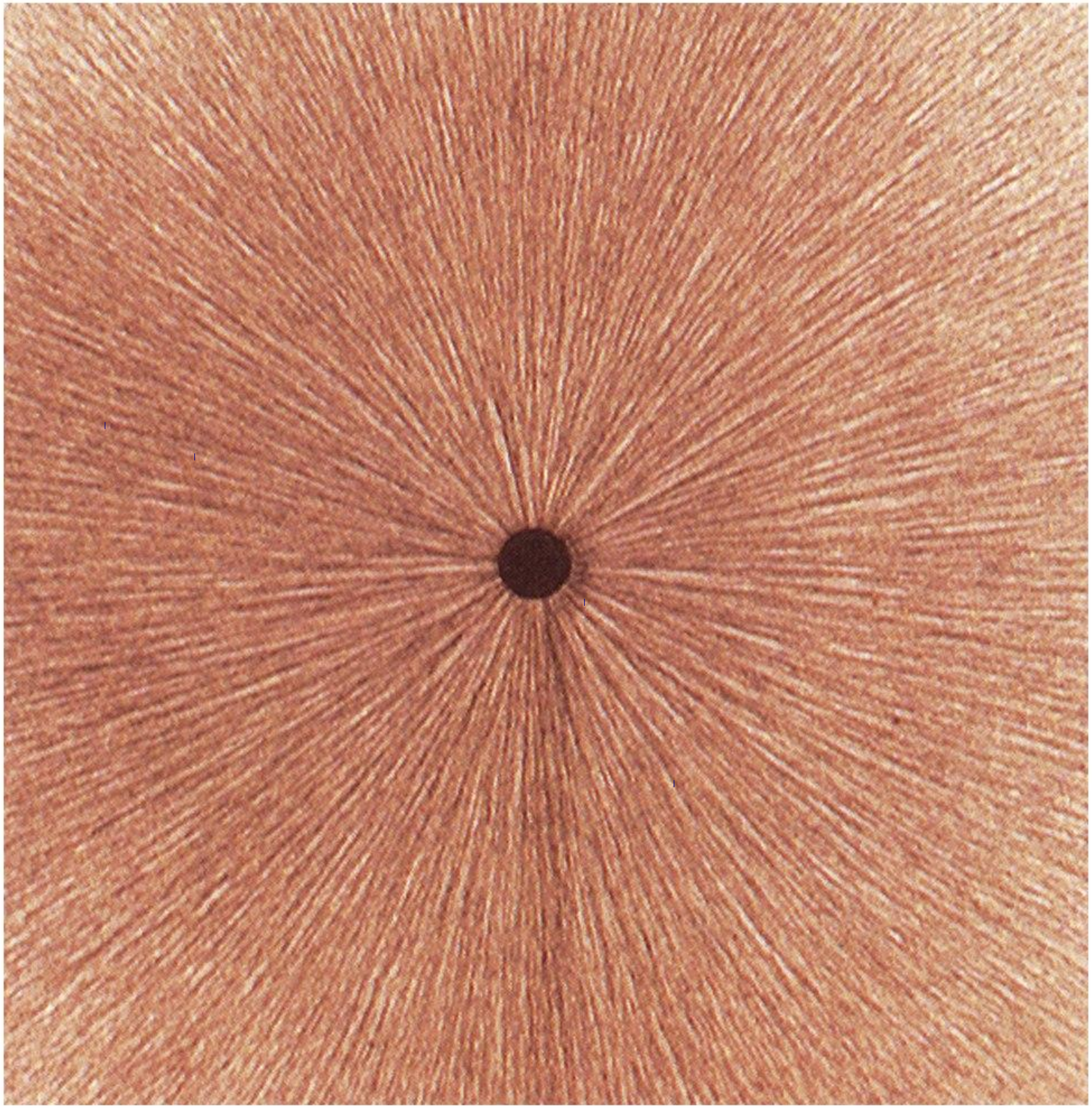
Dipole electric field – 2D view



Electric Field Lines

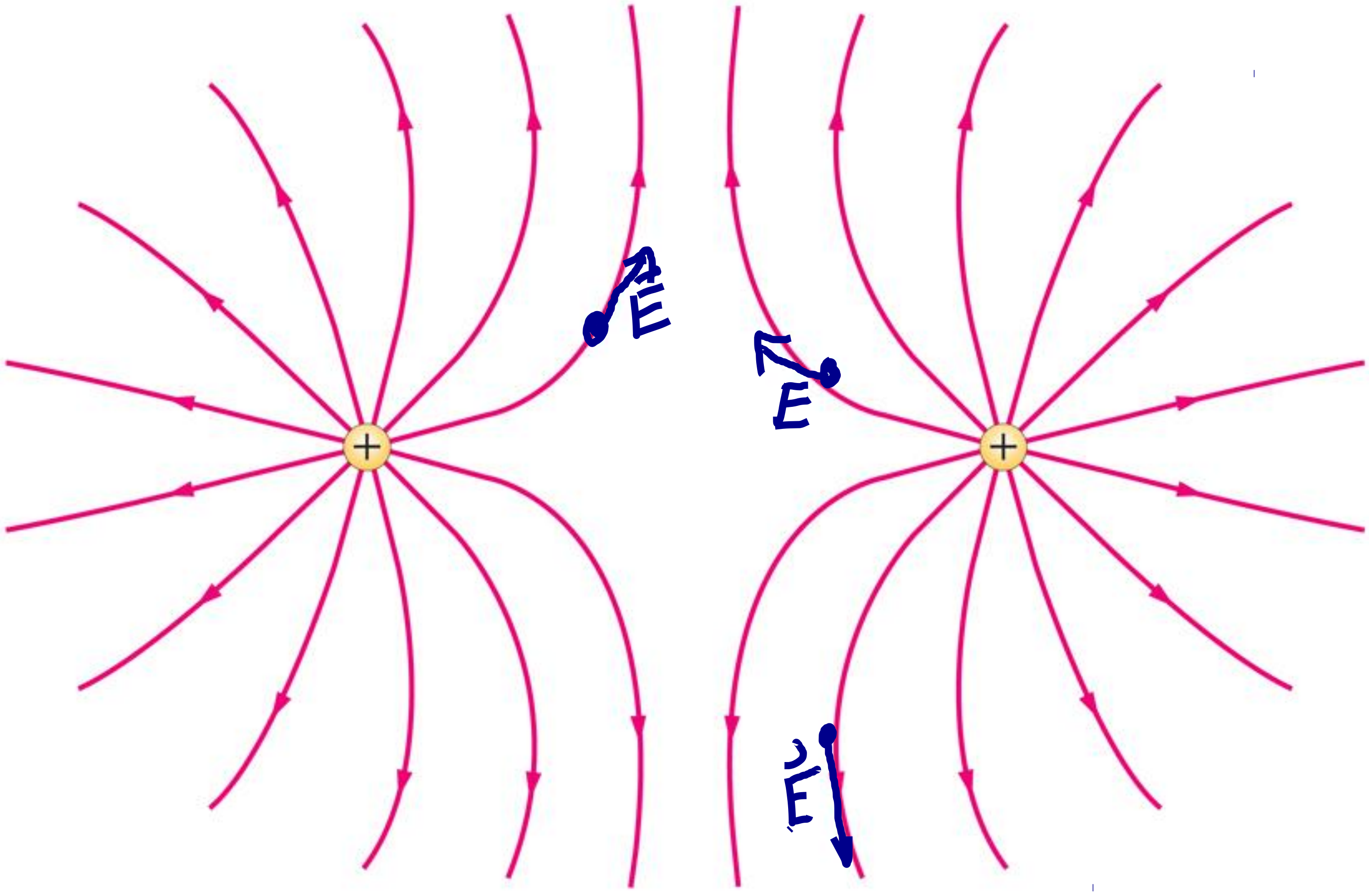
- Field lines start or end at charges or at infinity.
  - Lines are directed outwards from positive charges and inward towards negative charges.
  - # of lines starting or ending at a charge is proportional to the magnitude of that charge (constant of proportionality is arbitrary, i.e. up to you).



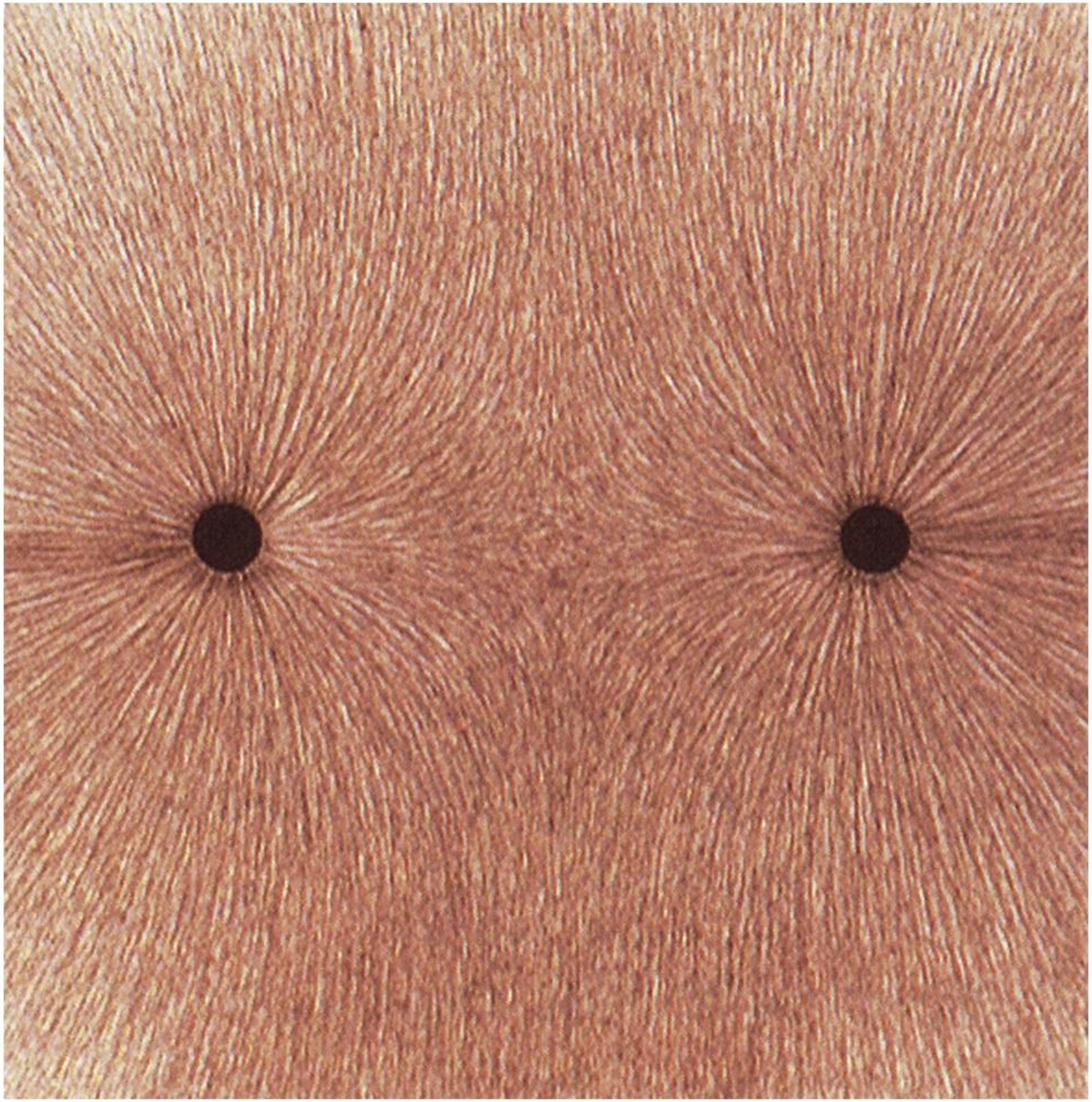


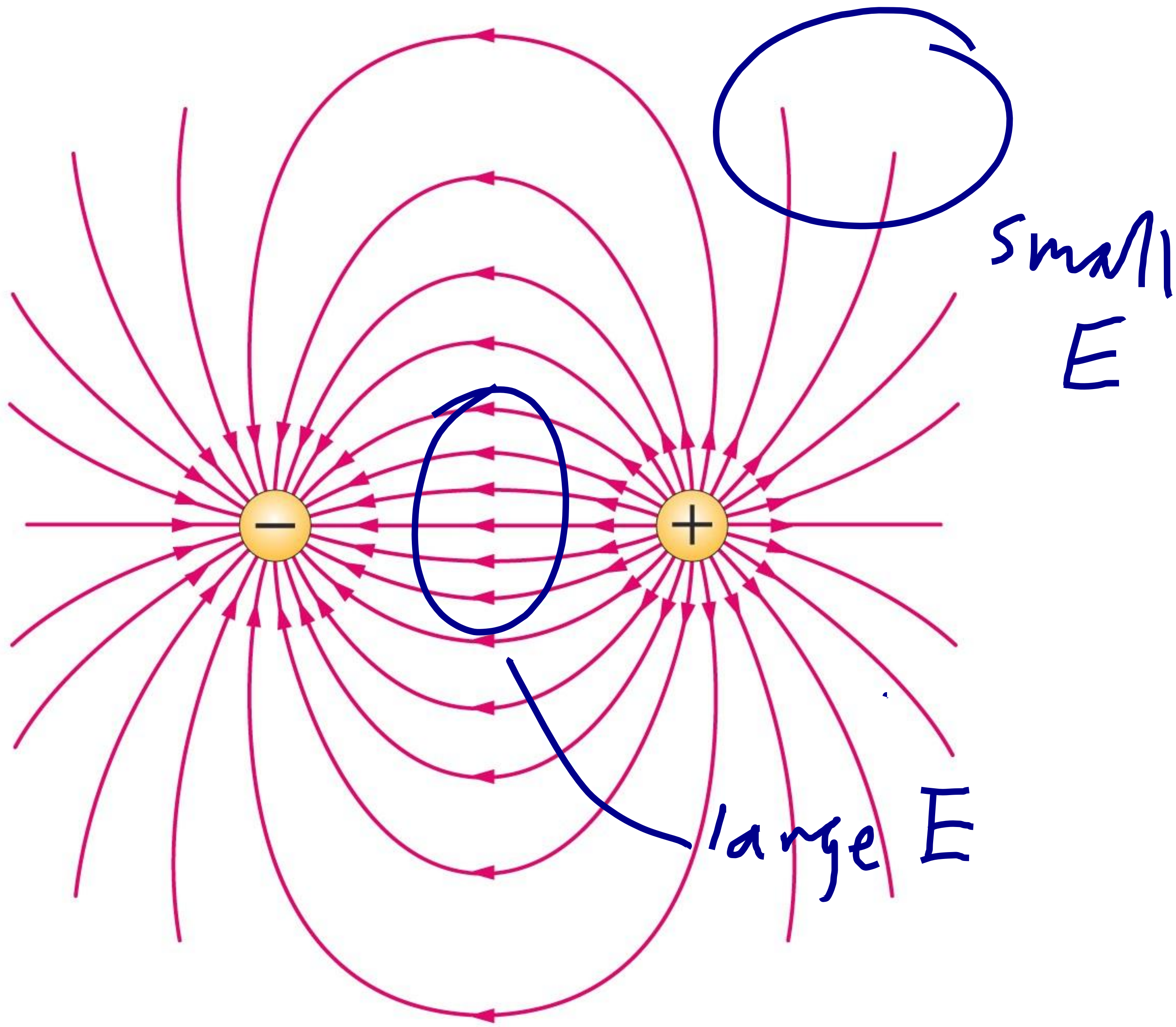
Electric Field Lines

- Relation to Electric Field
  - The Electric Field points along the tangent of the field lines. Charges do not in general move along the field lines!
  - The magnitude of the Electric Field is proportional to the density of field lines.

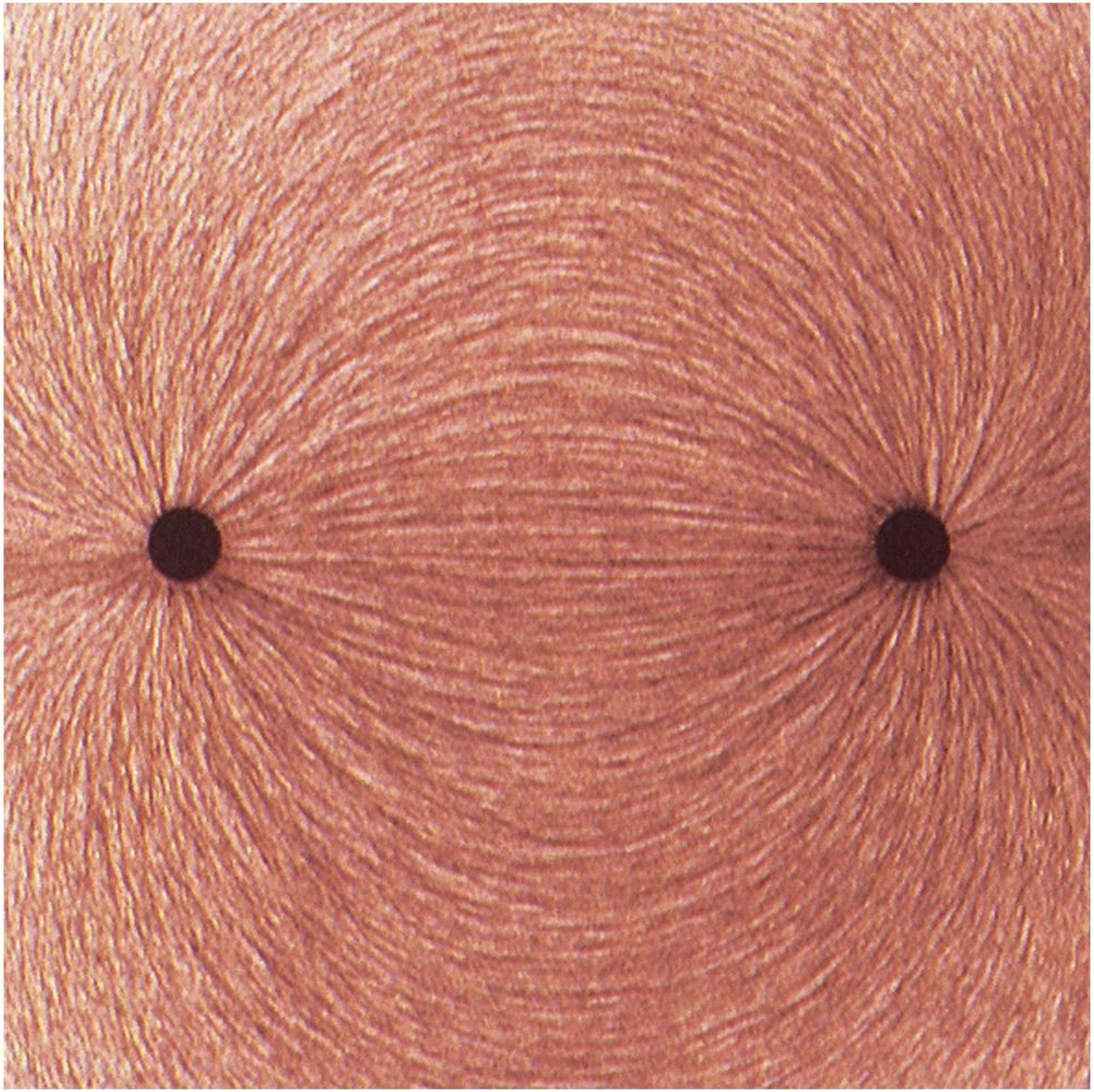


E
E
E





small E
large E



The figure shows the field lines for two charges. What might be the ratio of the left charge to the right charge?

1) 1:2
2) –1:2
3) 2:1
4) –2:1
5) 2:–1