electrostatics

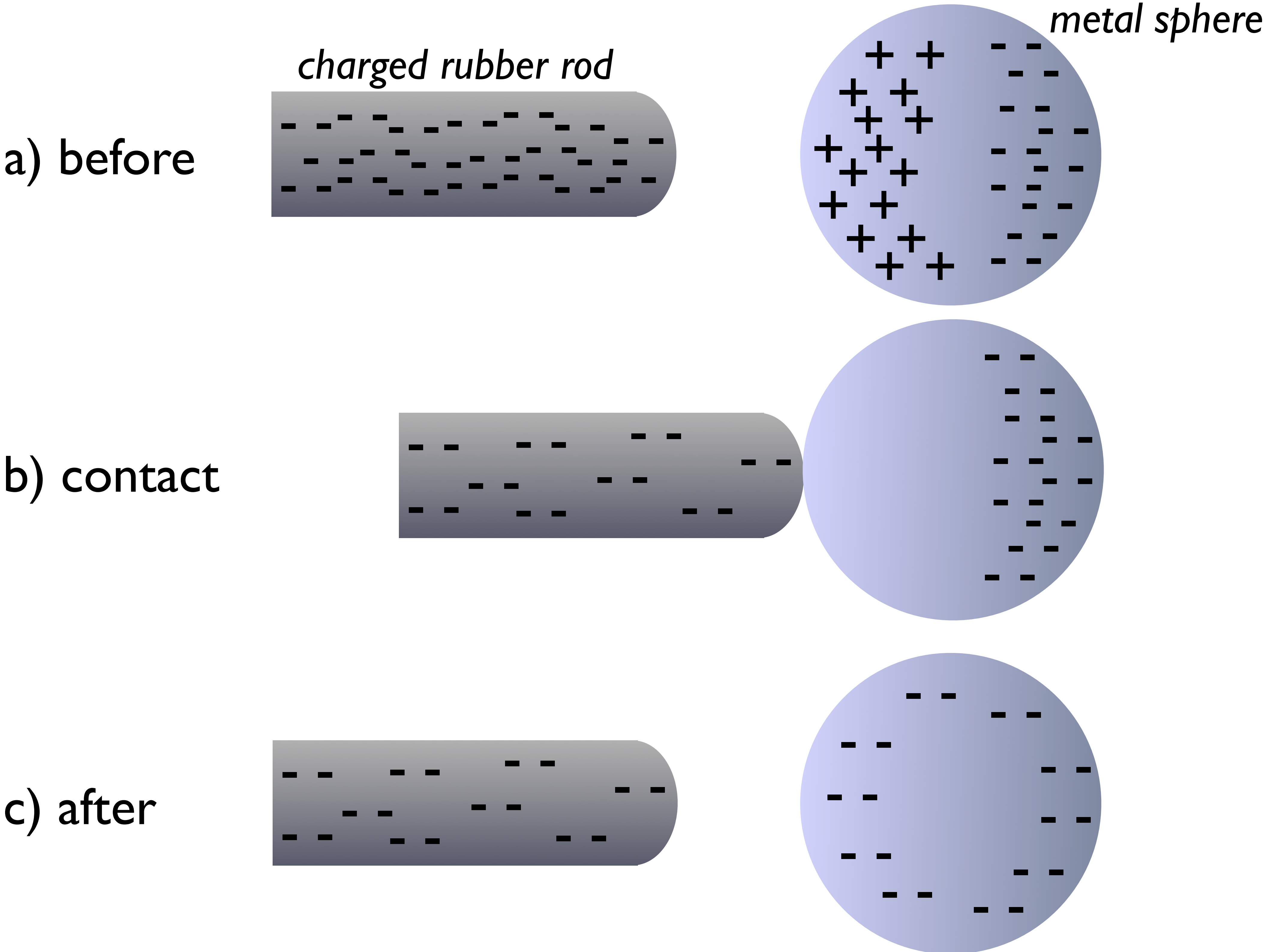
or, electric forces when nothing is moving.

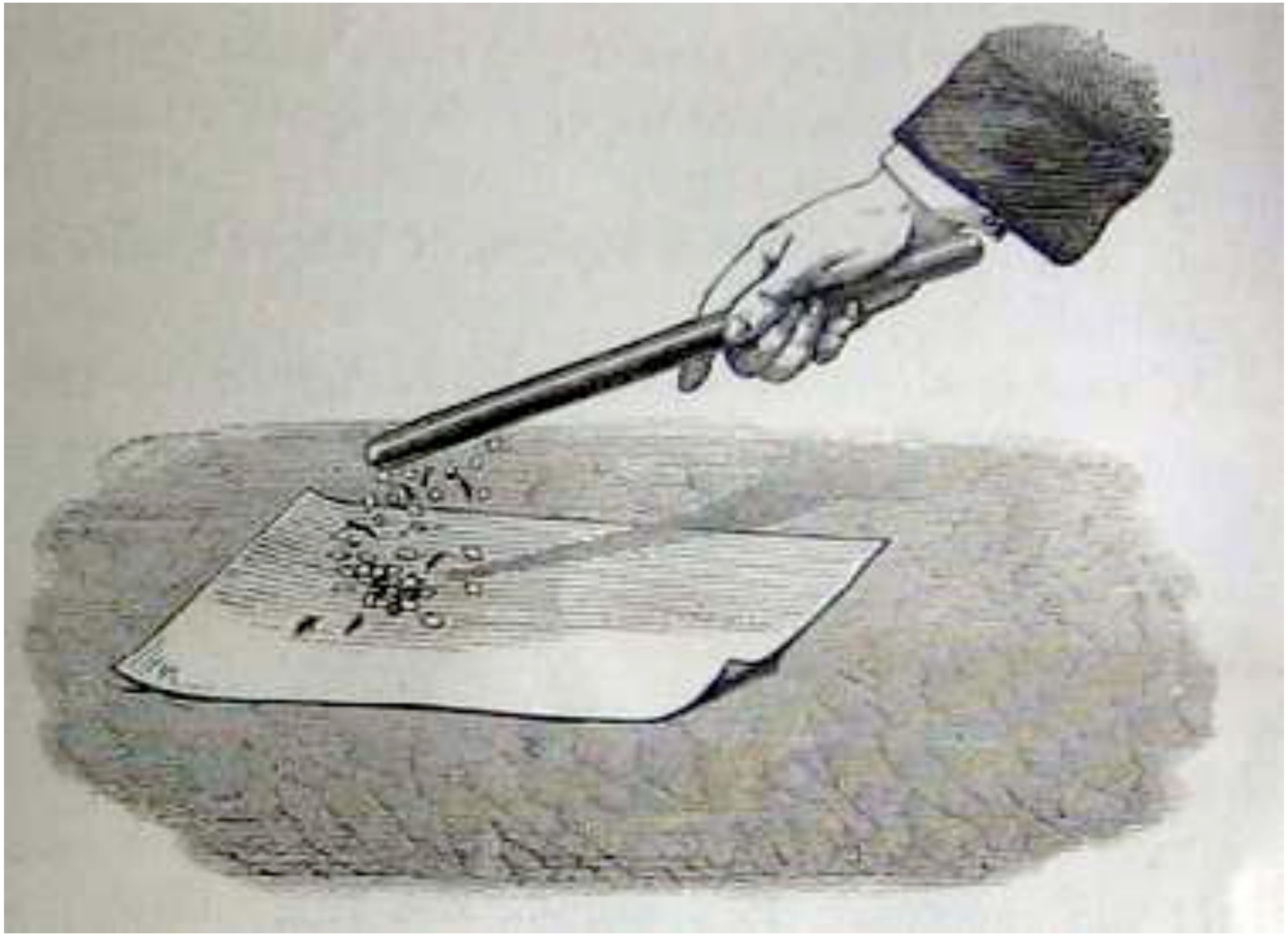
Summarizing the properties of charge:

1. Charge is quantized in units of $|e| = 1.6 \times 10^{-19}$ C
2. Electrons carry one unit of negative charge, $-e$
3. Protons carry one unit positive charge, $+e$
4. Objects become charged be gaining or losing electrons, not protons
5. Electric charge is always conserved

Table 3.1: *Properties of electrons, protons, and neutrons*

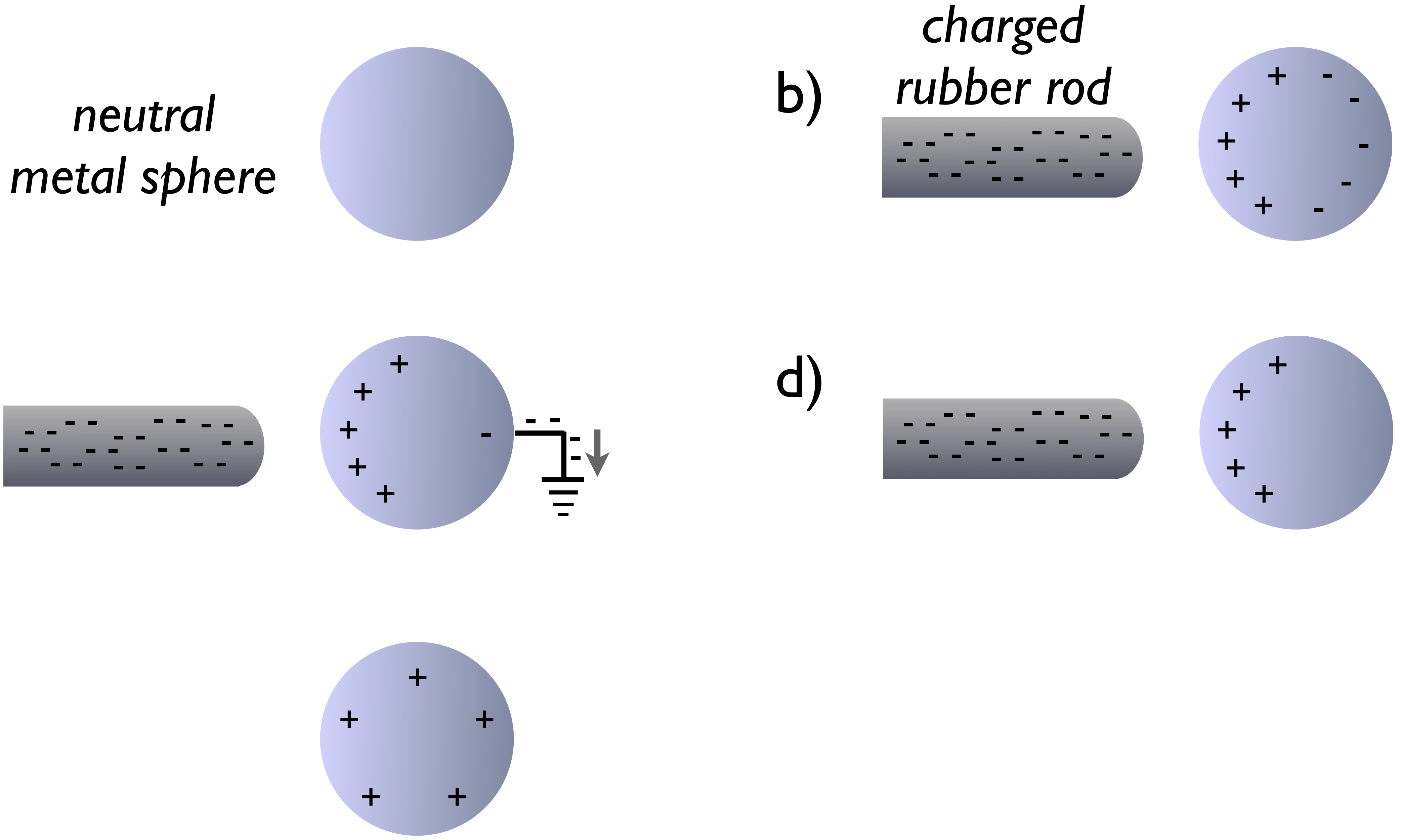
Particle	**Charge [C]**	$[e]$	**Mass [kg]**
electron (e^-)	-1.60×10^{-19}	-1	9.11×10^{-31}
proton (p^+)	$+1.60\times10^{-19}$	$+1$	1.67×10^{-27}
neutron (n^0)	0	0	1.67×10^{-27}


metal sphere
charged rubber rod
a) before
b) contact
c) after

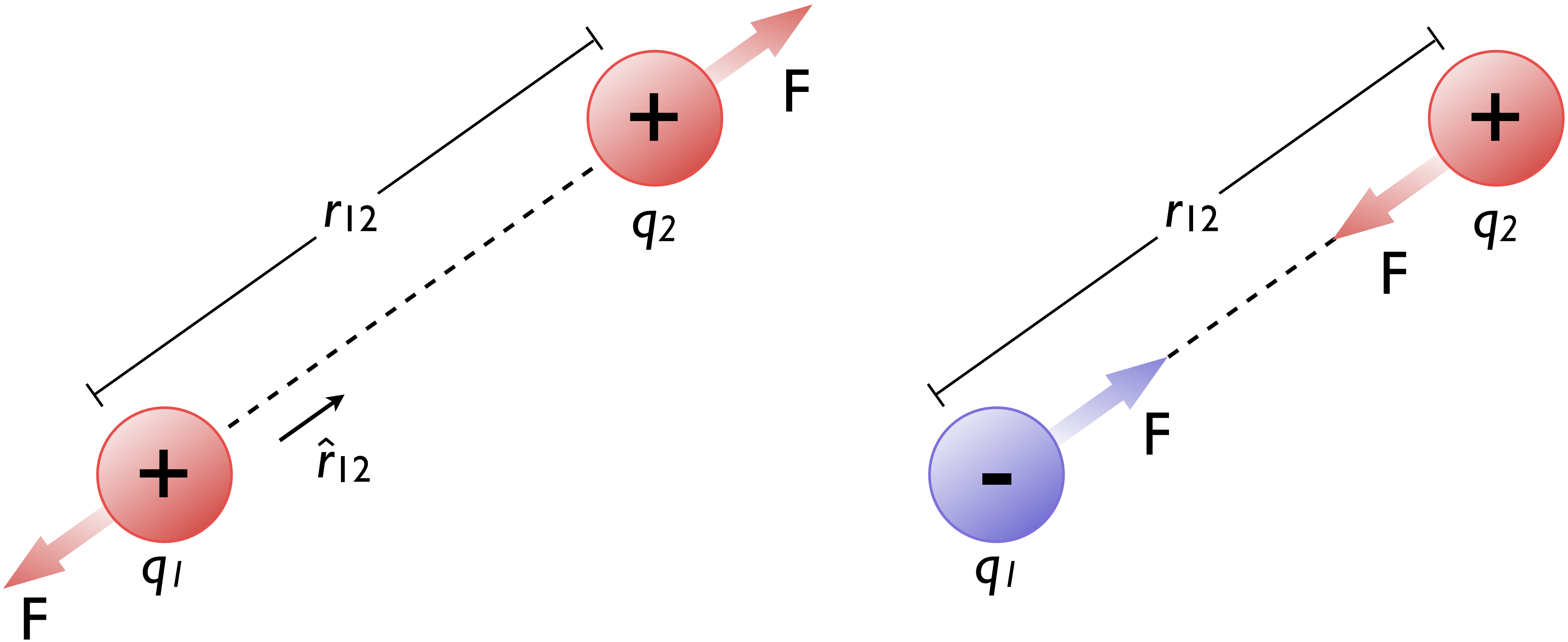


“Little pieces of tissue paper (or light grains of sawdust) are attracted by a glass rod rubbed with a silk handkerchief (or by a piece of sealing wax or a rubber comb rubbed with flannel).”

- from a random 1902 science book



neutral
metal sphere
b)
charged
rubber rod
d)

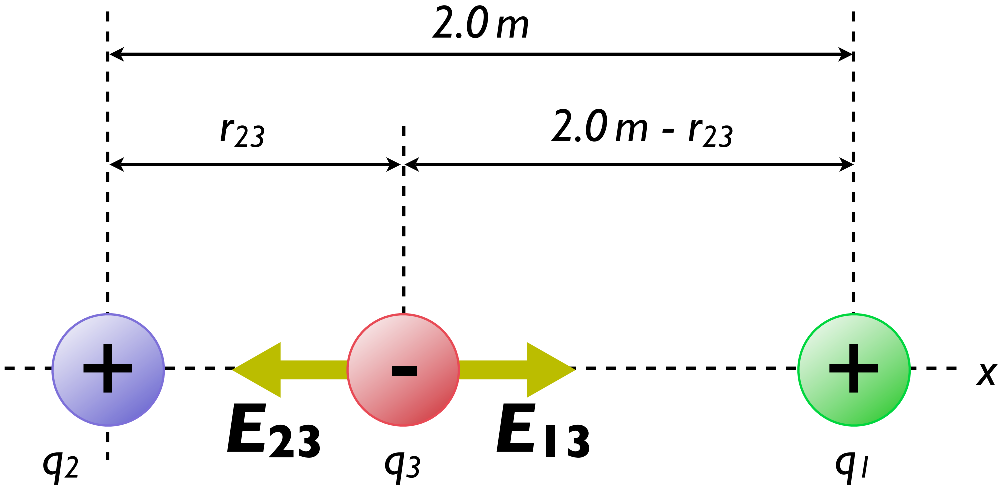


F
+
r_{12}
q_2
+
$\hat{r}_{12}$
q_1
F
F
+
r_{12}
q_2
F
-
F
q_1

Table 3.2: *Approximate electric field values, in [N/C]*

Source	$\lvert\vec{\mathbf{E}}\rvert$	**Source**	$\lvert\vec{\mathbf{E}}\rvert$
Fluorescent lighting tube	10	Atmosphere (fair weather)	10^2
Balloon rubbed on hair	10^3	Atmosphere (under thundercloud)	10^4
Photocopier	10^5	Spark in air	10^6
Across a transistor gate dielectric	10^9	Near electron in hydrogen atom	10^{11}

2. Three point charges lie along the x axis, as shown at left. A positive charge $q_1 = 15\,\mu\text{C}$ is at $x = 2\,\text{m}$, and a positive charge of $q_2 = 6\,\mu\text{C}$ is at the origin. Where must a *negative* charge q_3 be placed on the x-axis **between the two positive charges** such that the resulting electric force on it is zero?



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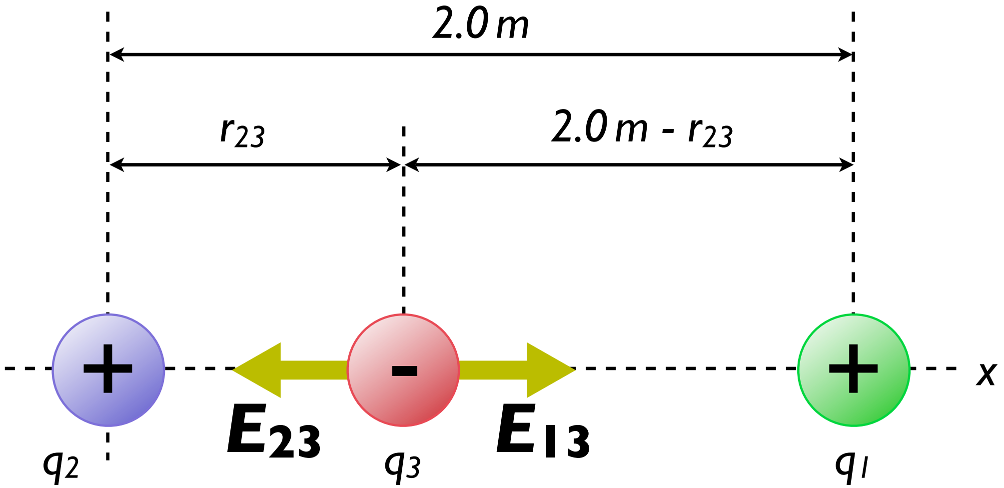
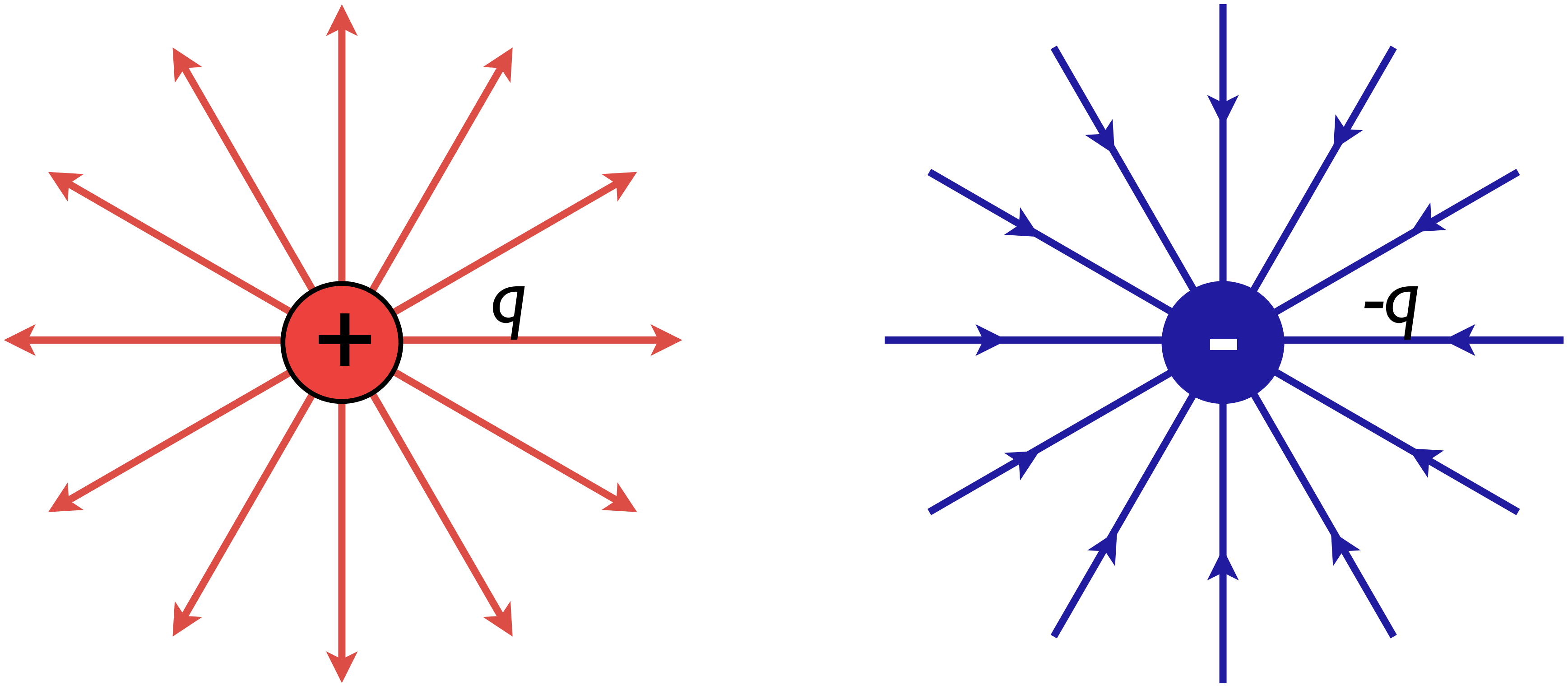


~ 0.77m from q_2

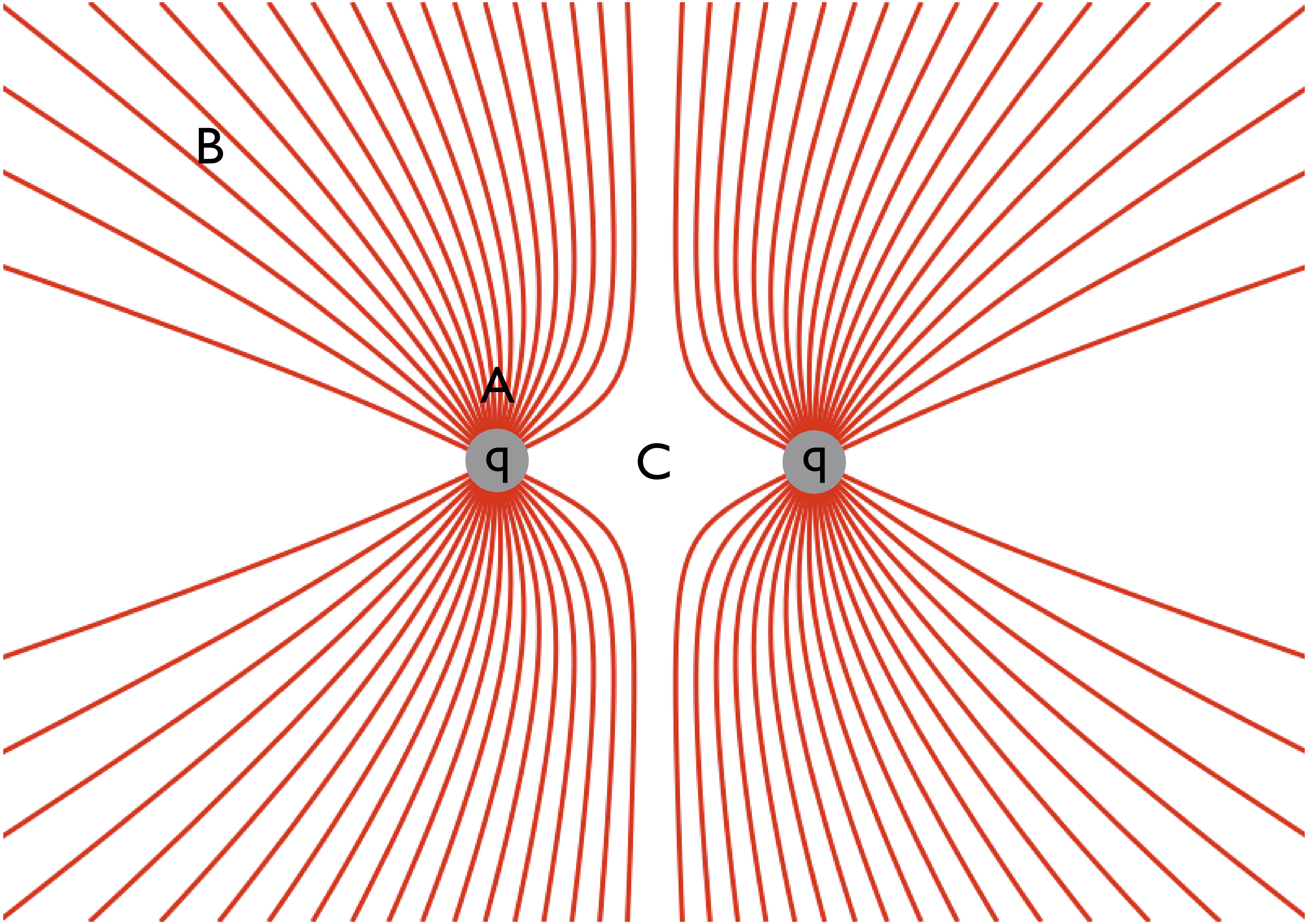
or

~ 1.23m from q_1

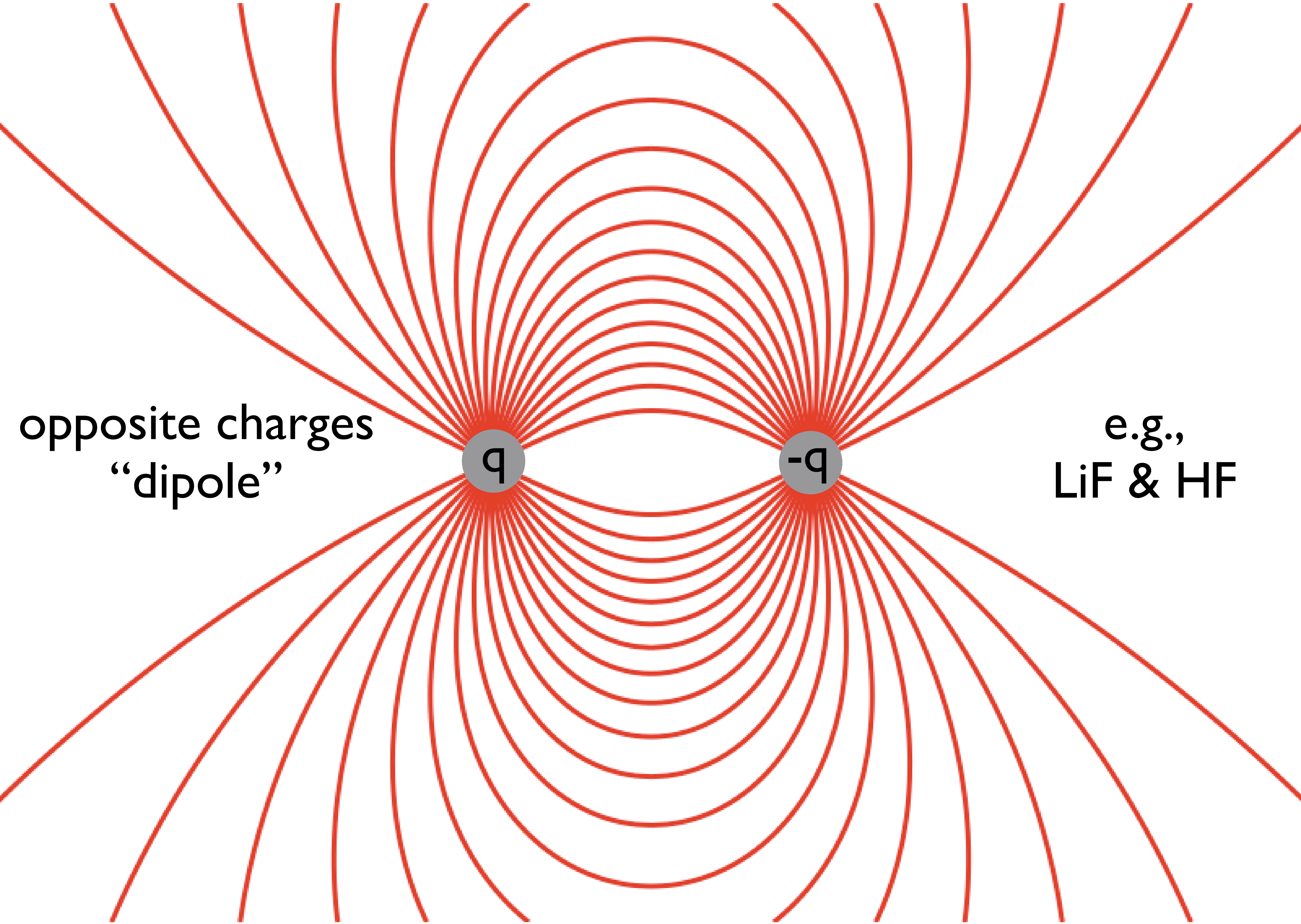


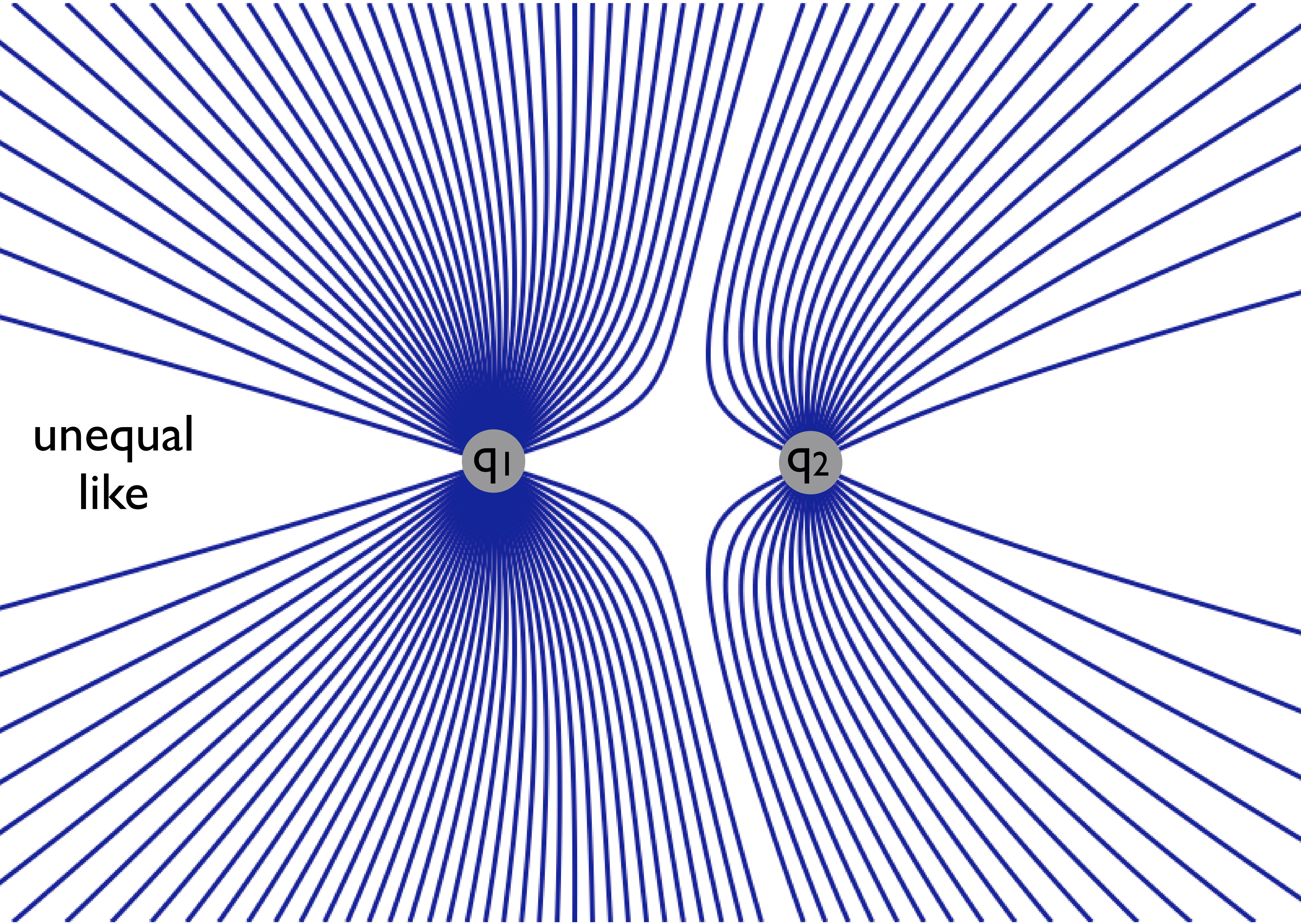
(a) (b)

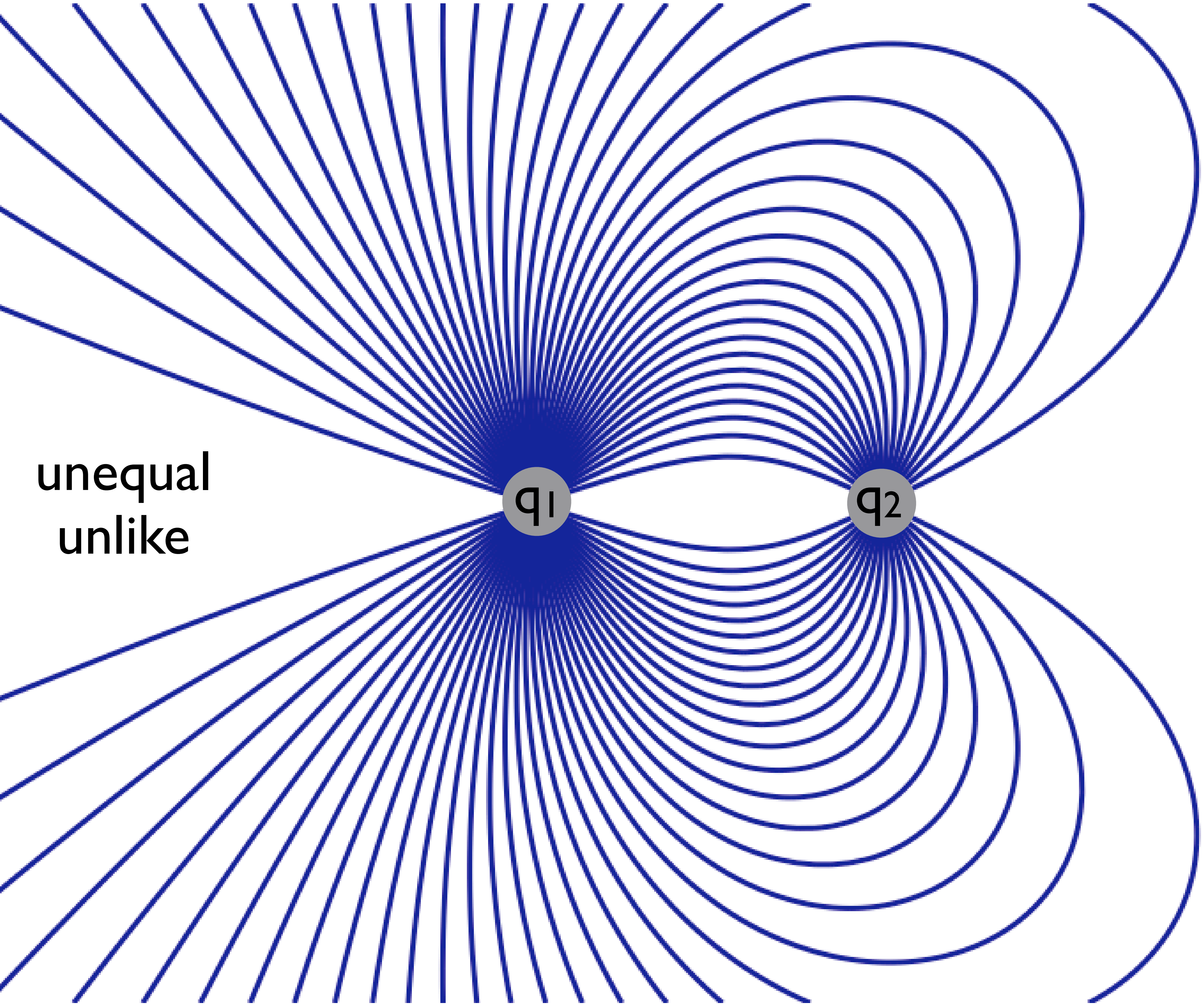
equal charges

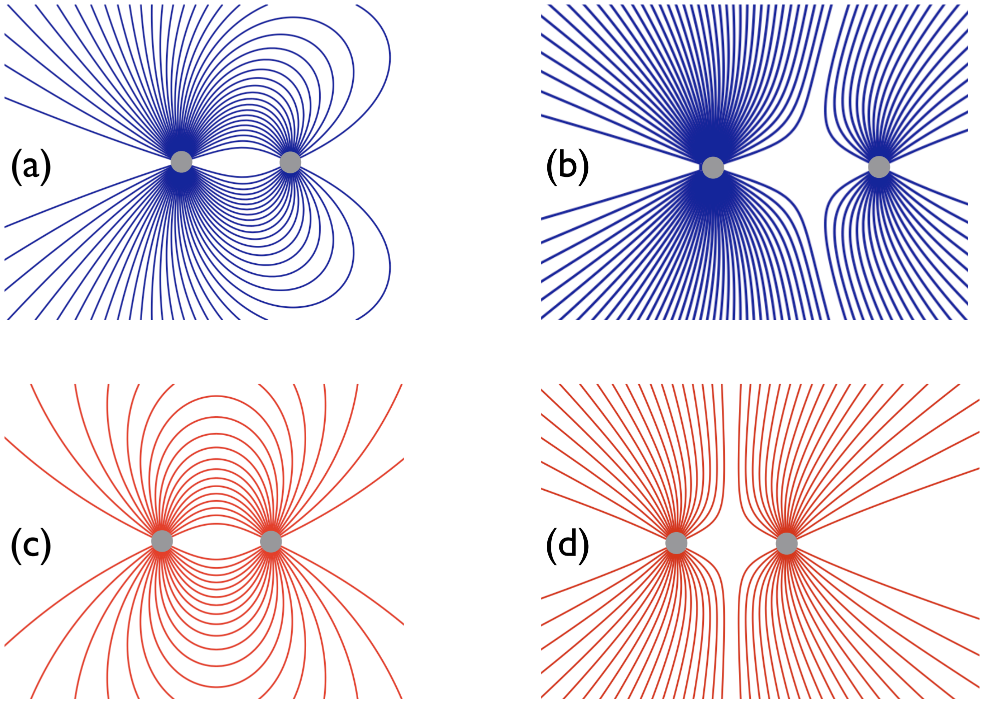


field: A > B > C


opposite charges
“dipole”
q
-q
e.g.,
LiF & HF

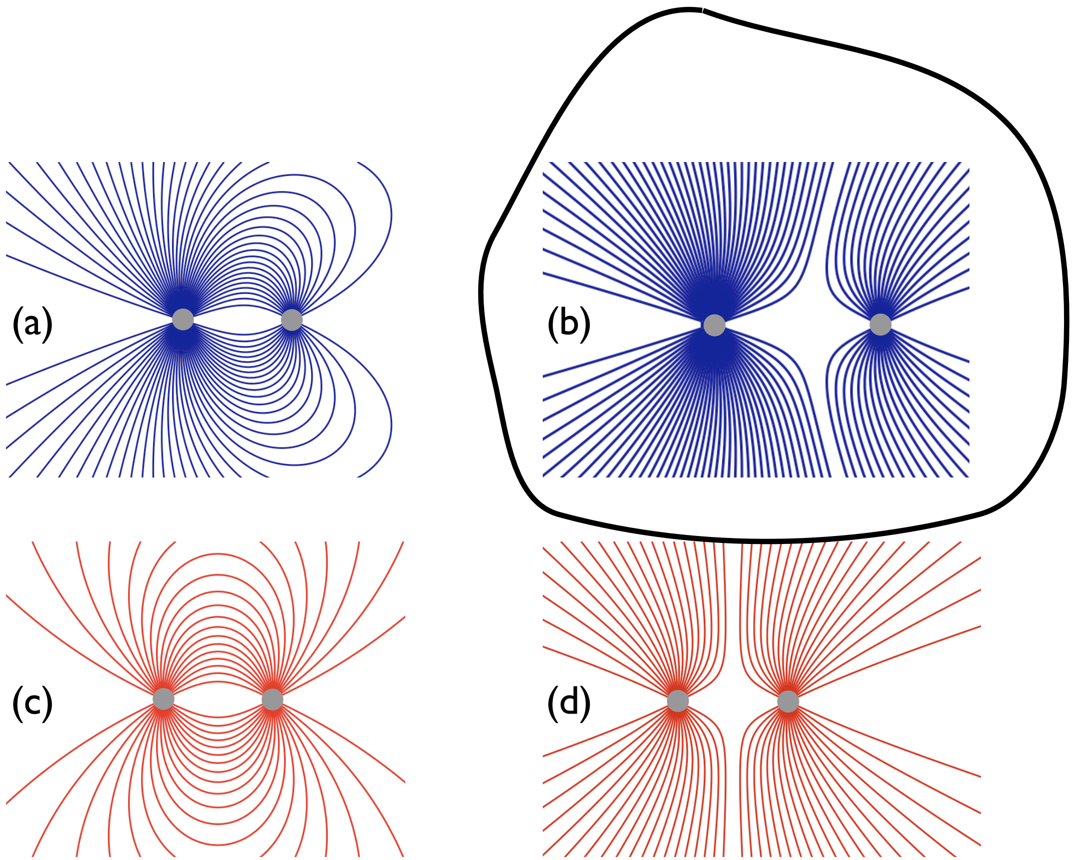

unequal
like
q1
q2


unequal
unlike
q1
q2



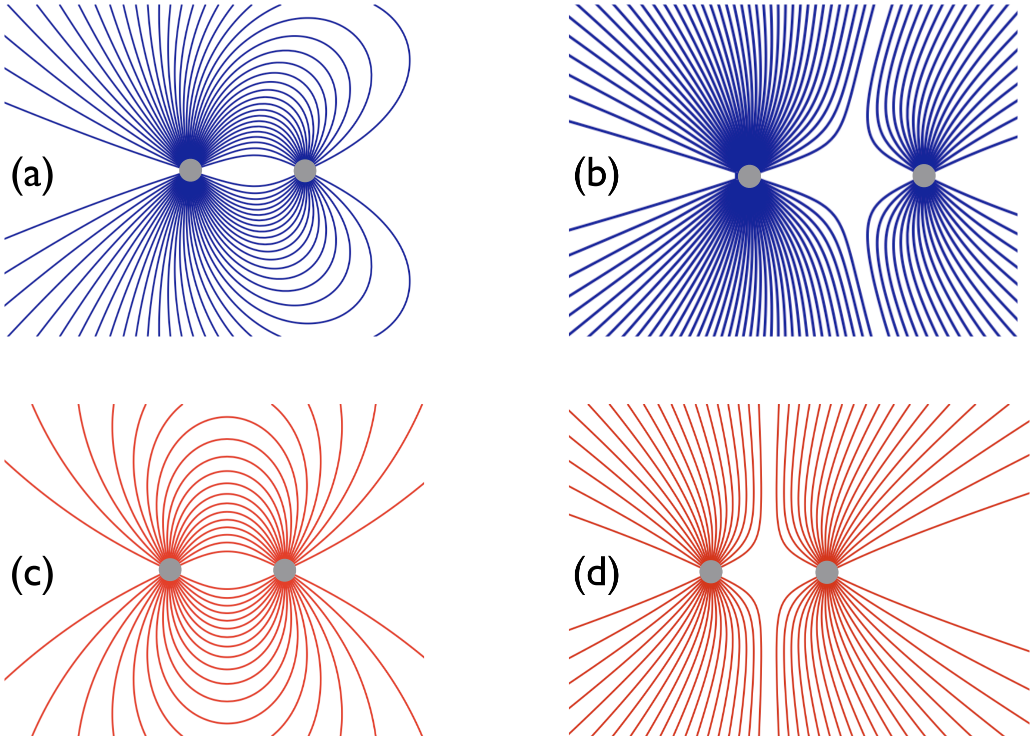
9. Which set of electric field lines could represent the electric field near two charges of the *same sign*, but *different magnitudes*?

- ☐ a
- ☐ b
- ☐ c
- ☐ d



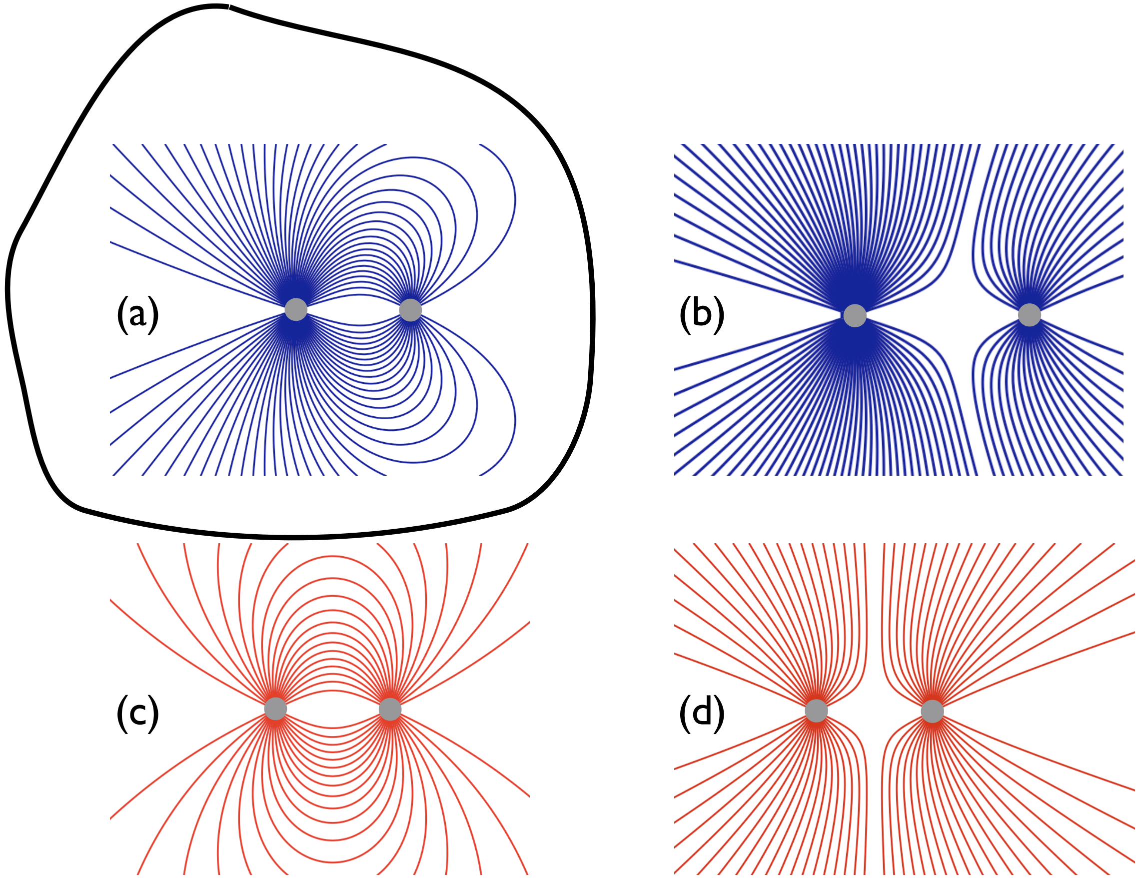
9. Which set of electric field lines could represent the electric field near two charges of the *same sign*, but *different magnitudes*?

- ☐ a
- ☐ b
- ☐ c
- ☐ d



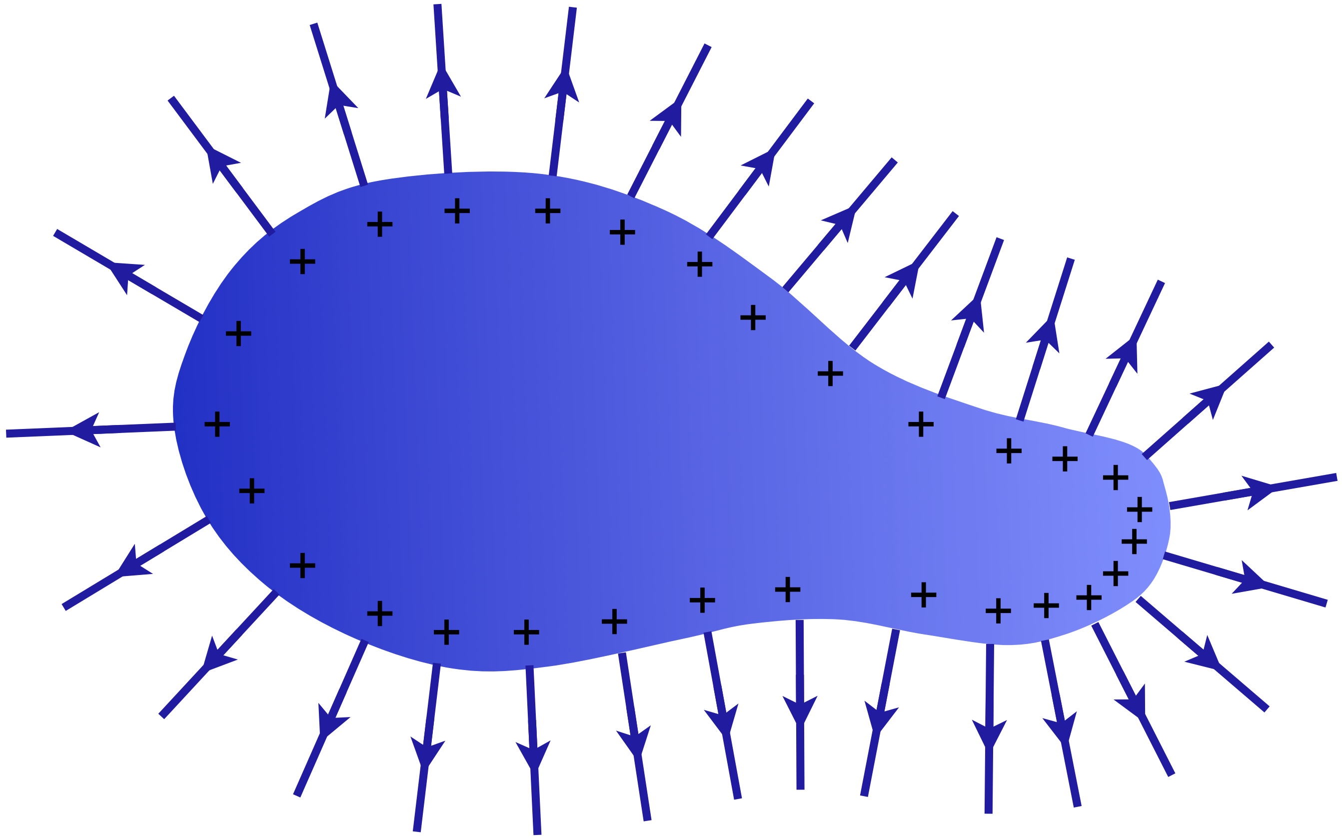
10. Referring again to the figure above, which set of electric field lines could represent the electric field near two charges of *opposite sign* and *different magnitudes*?

- ☐ a
- ☐ b
- ☐ c
- ☐ d

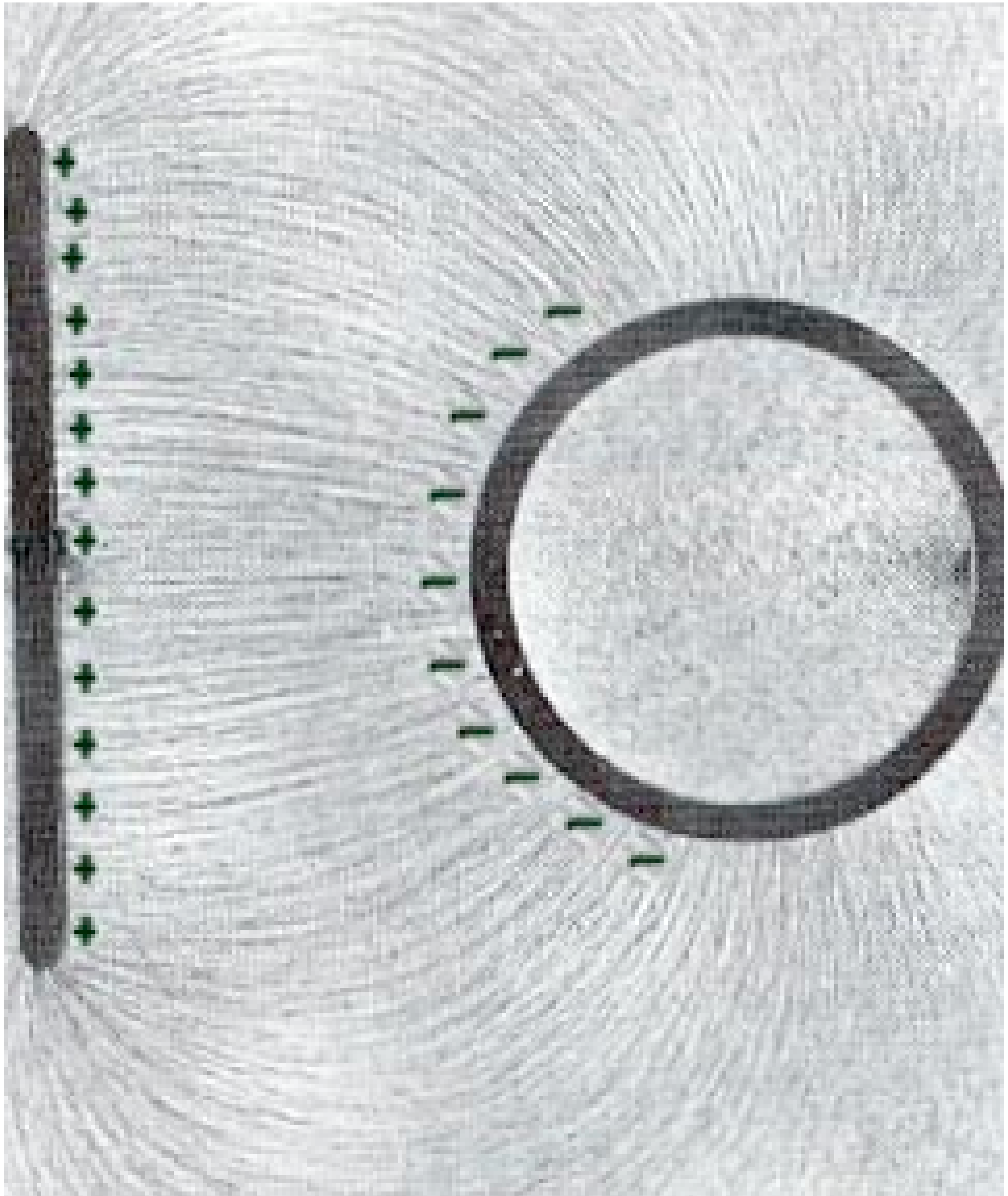


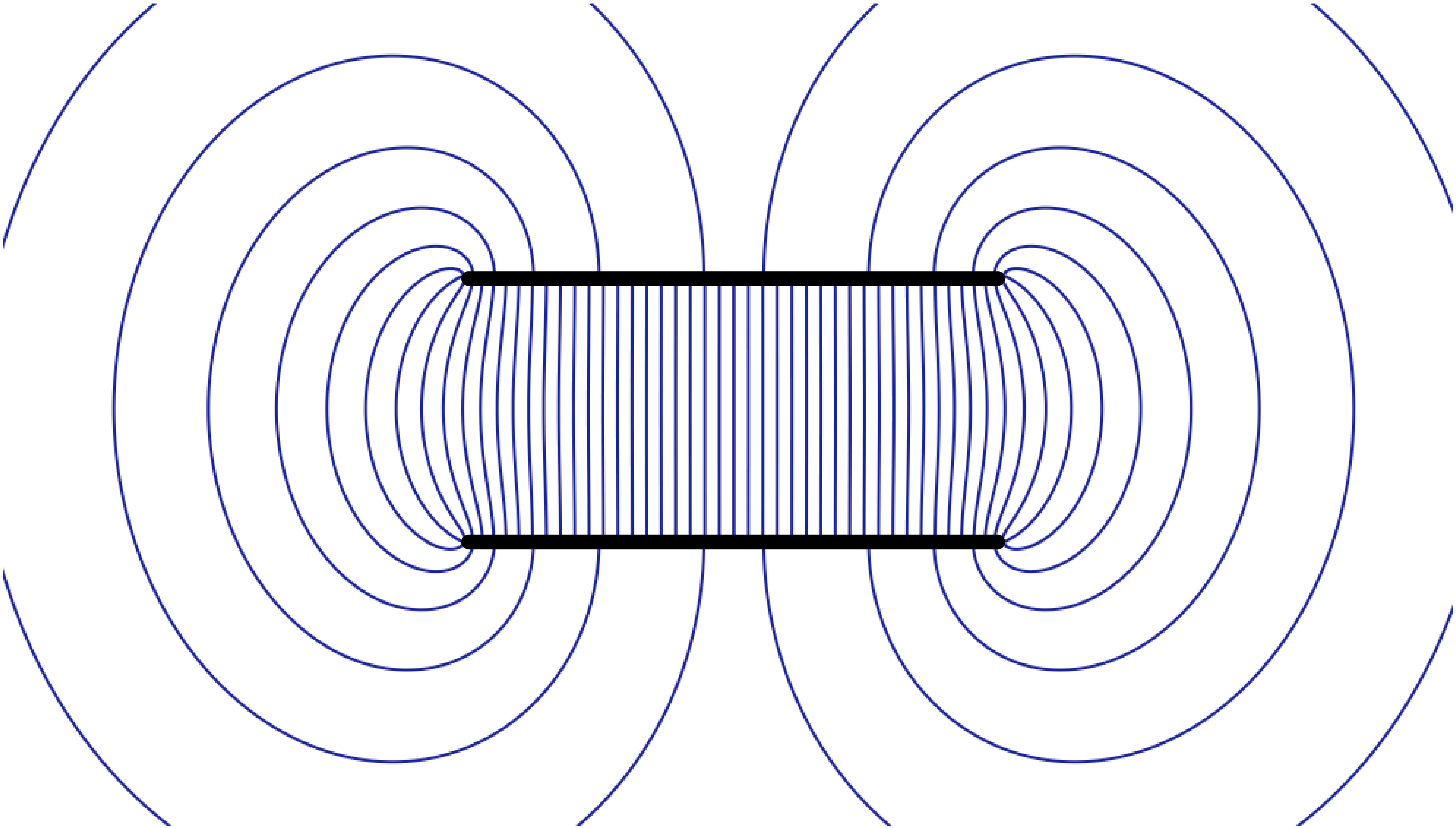
10. Referring again to the figure above, which set of electric field lines could represent the electric field near two charges of *opposite sign* and *different magnitudes*?

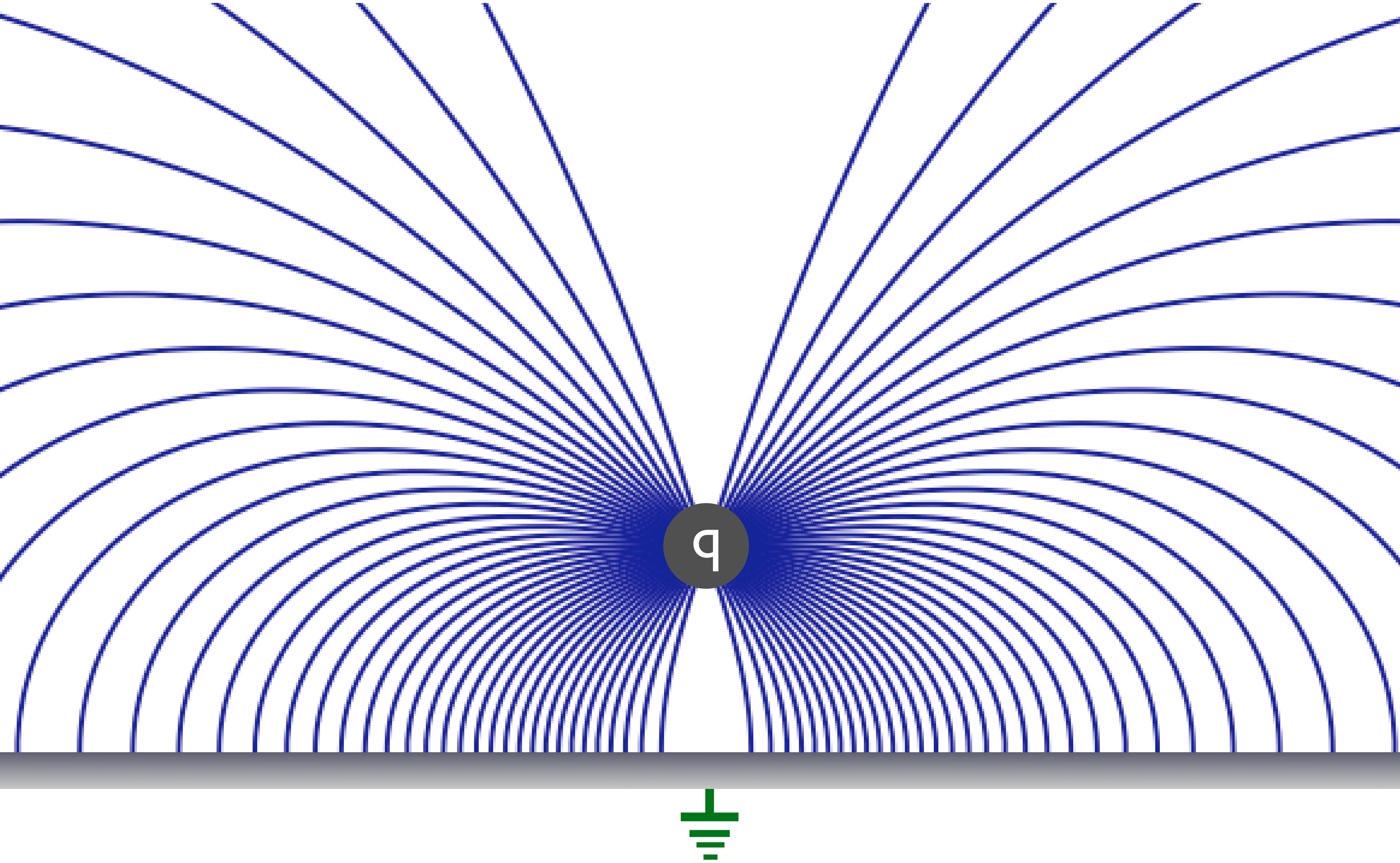
- ☐ a
- ☐ b
- ☐ c
- ☐ d

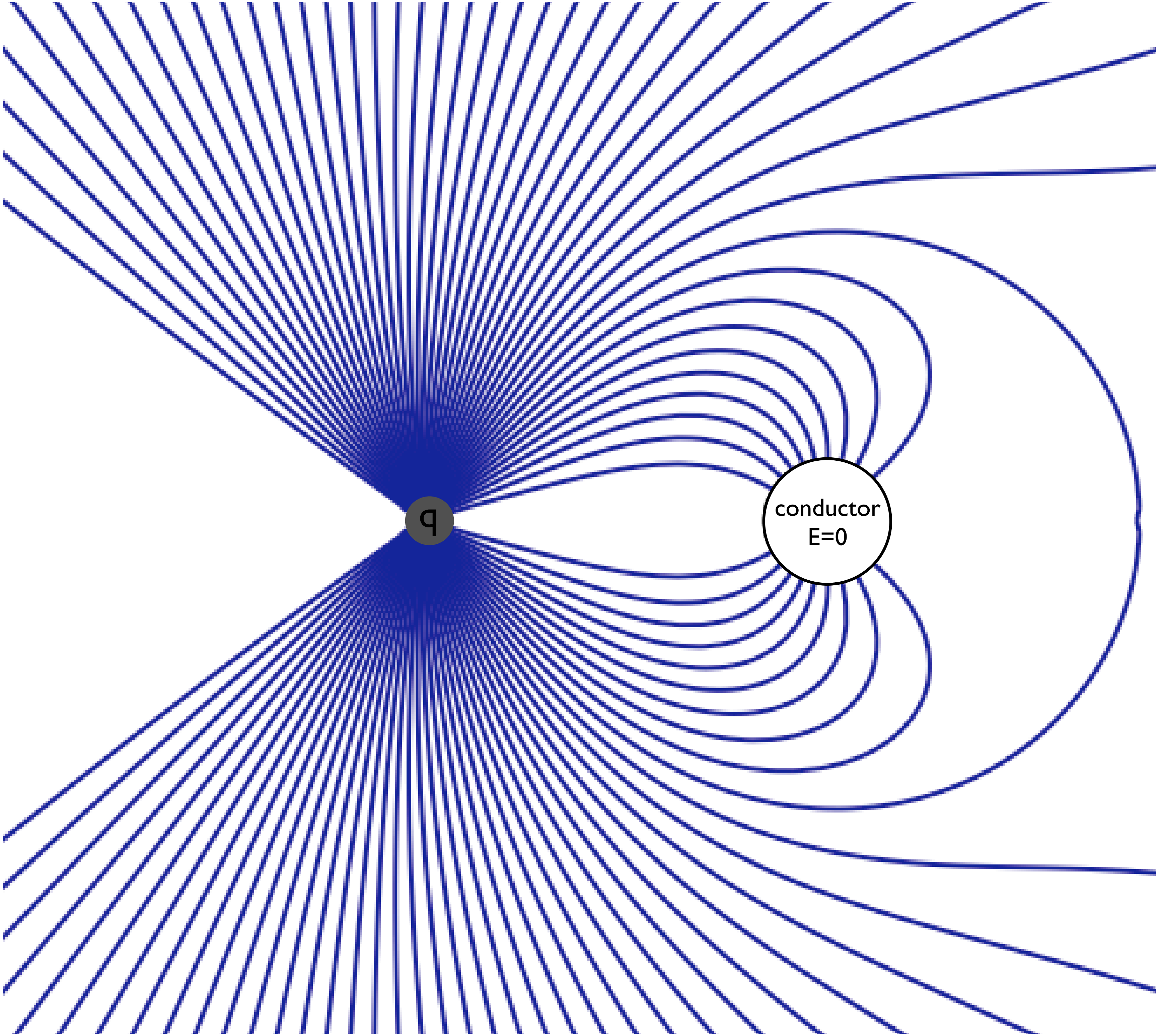


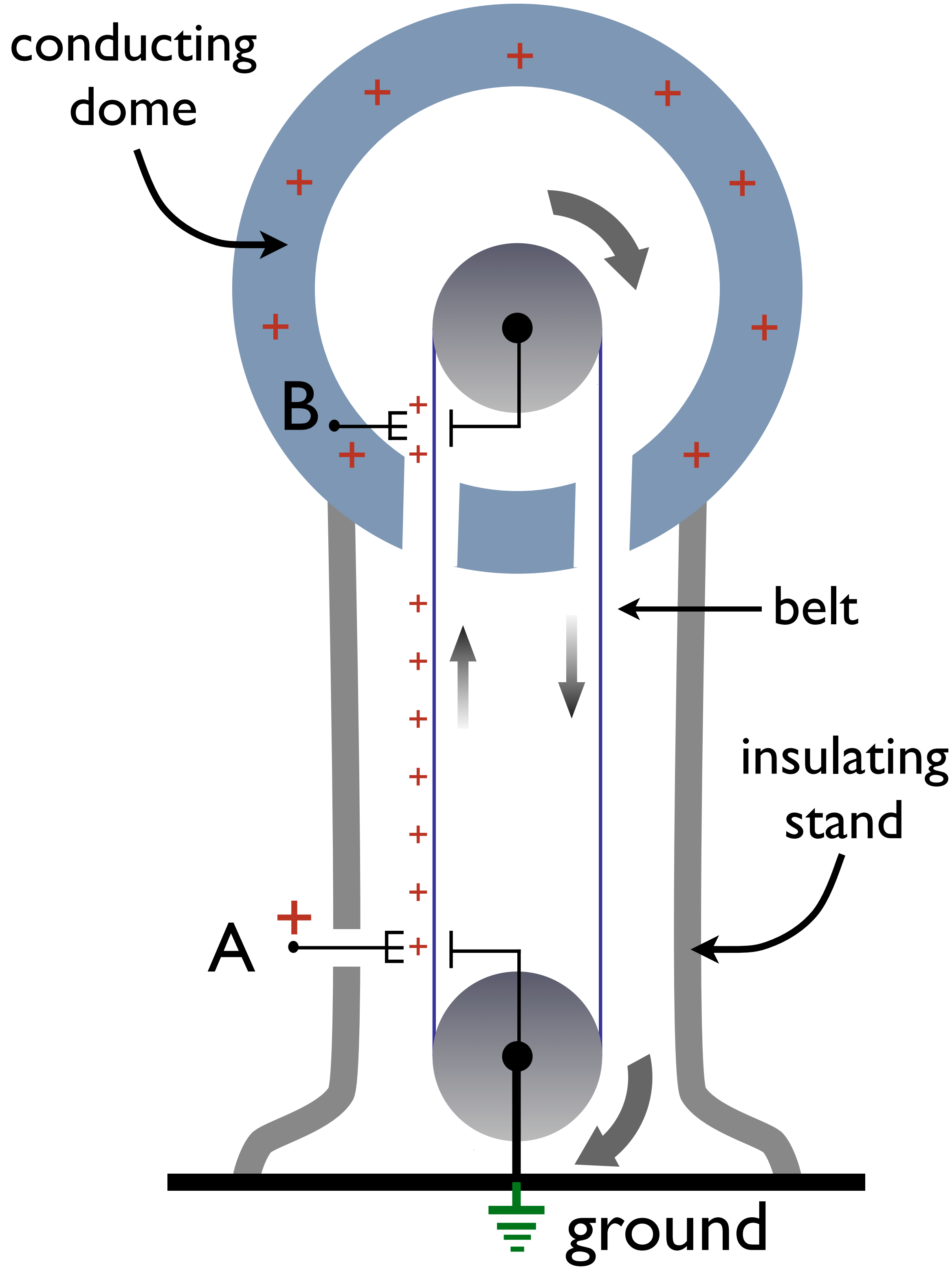
~~amoeba~~ conductor

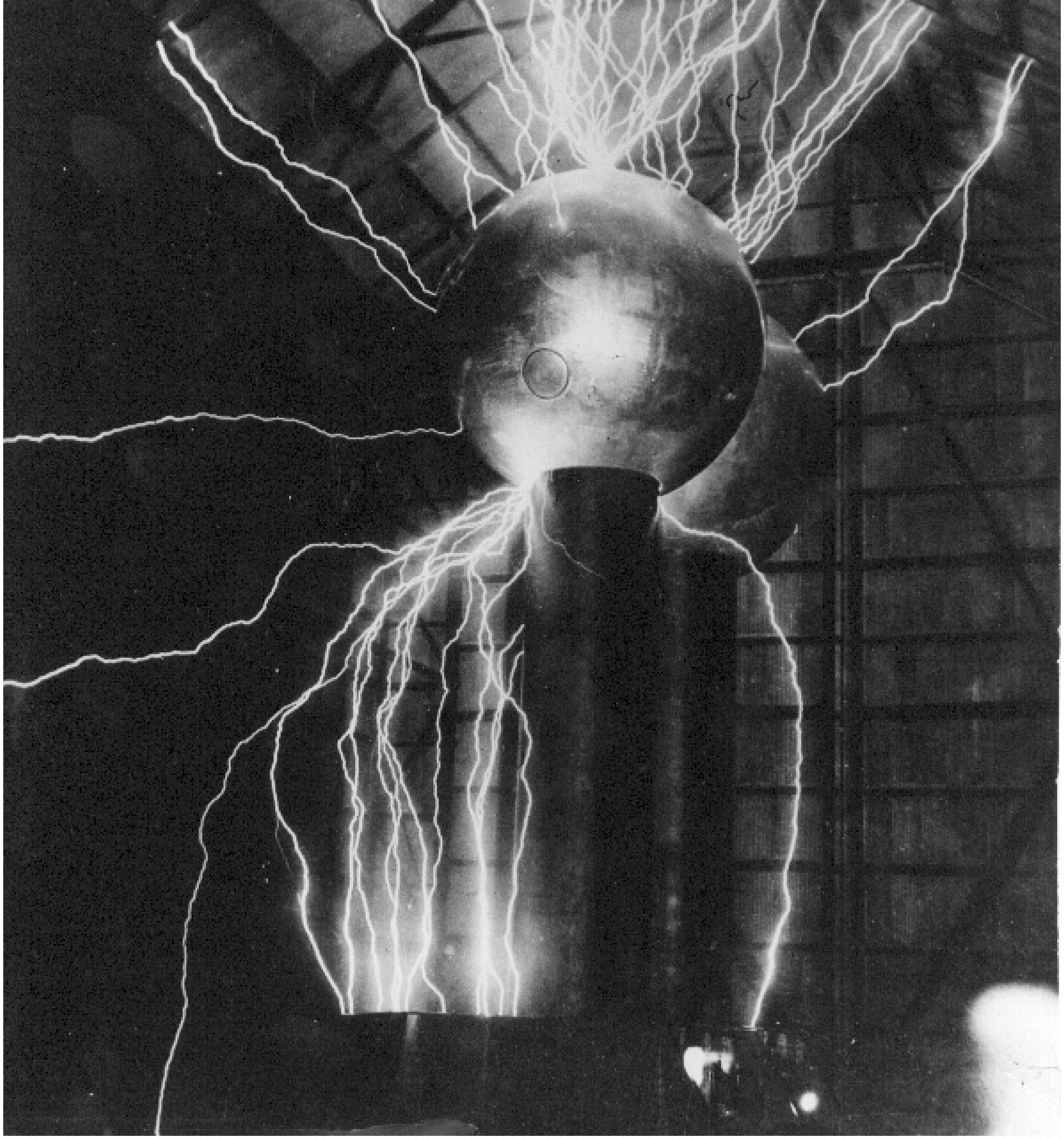


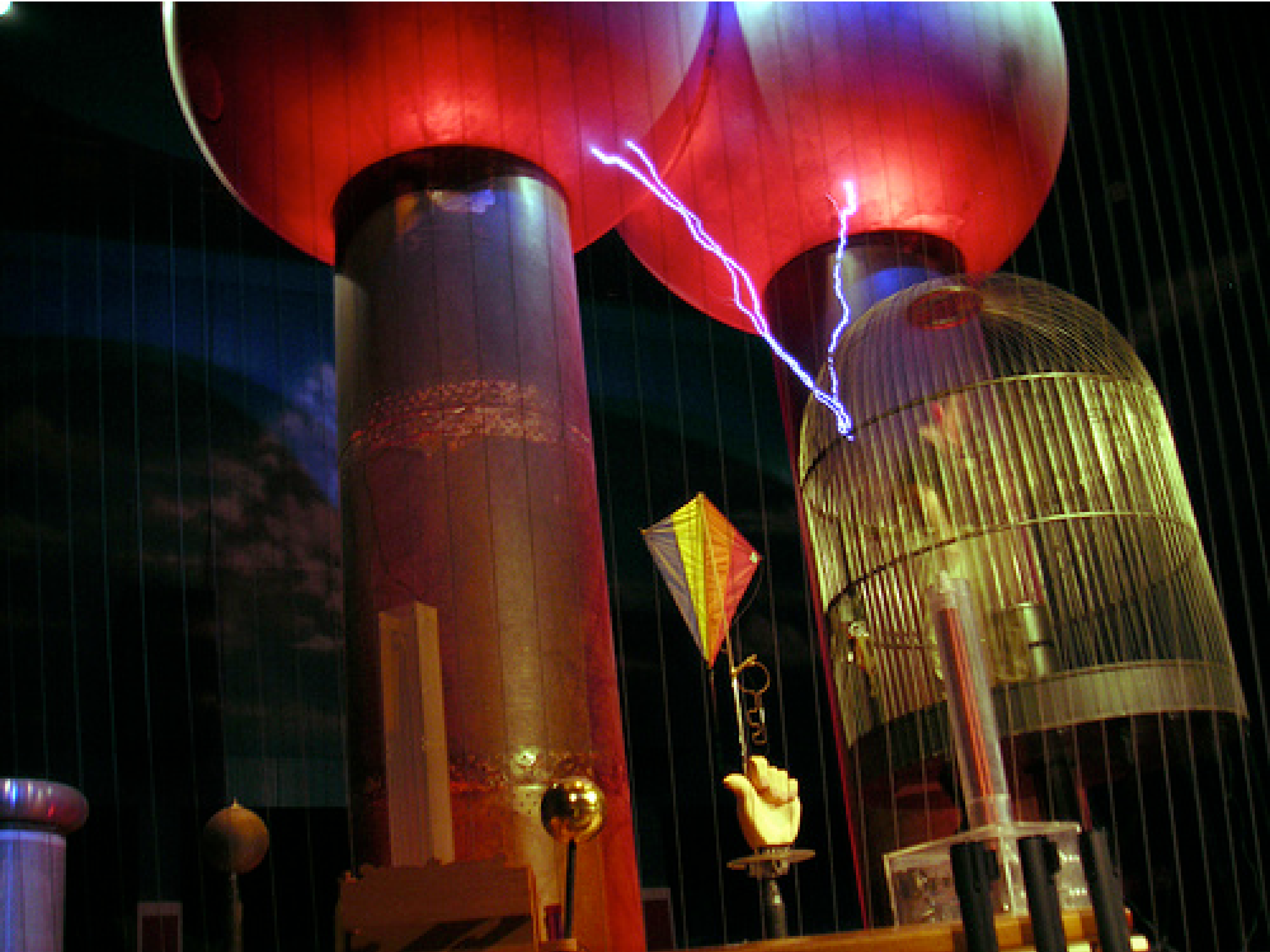


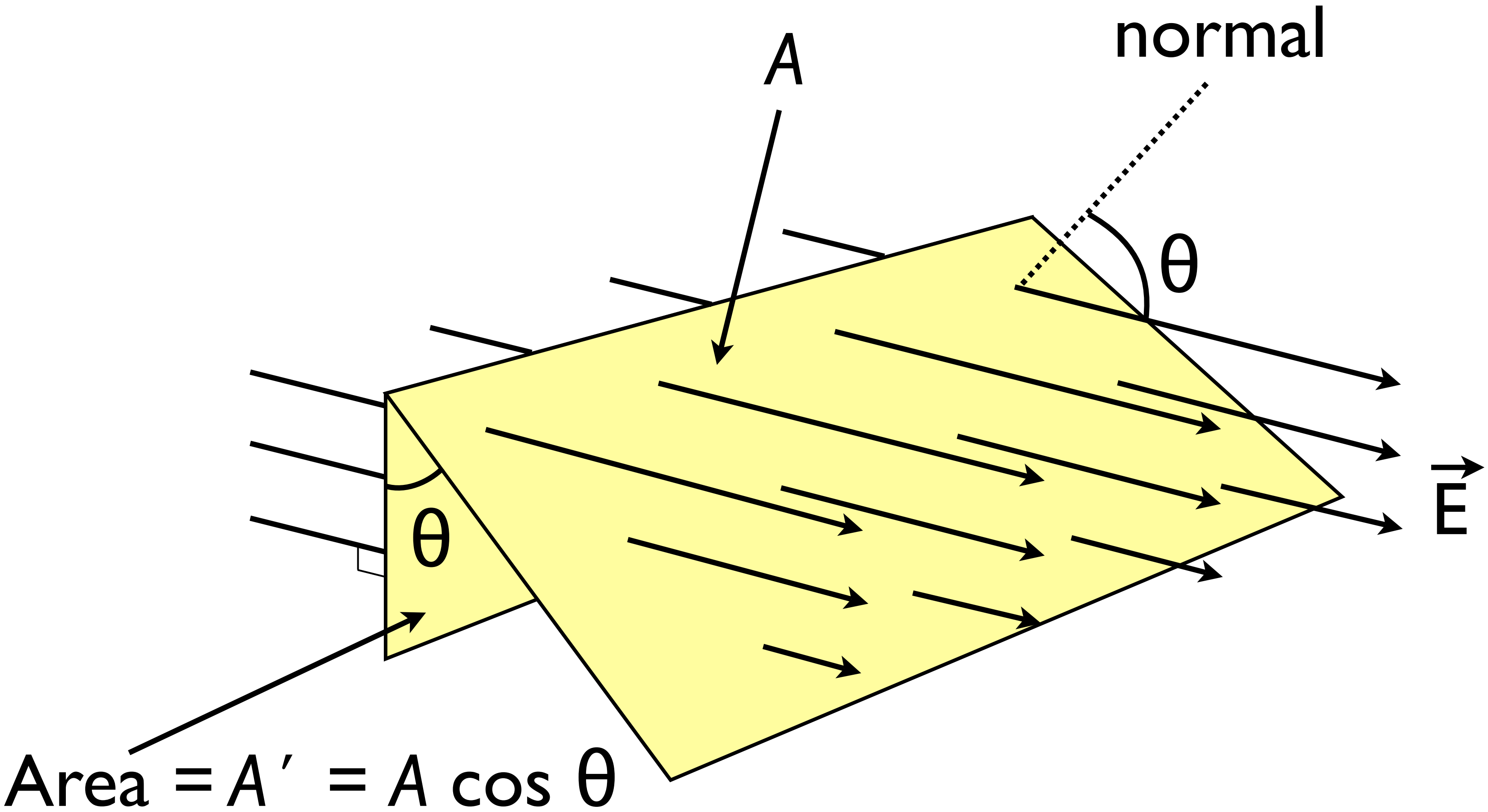

q


q
conductor
E=0

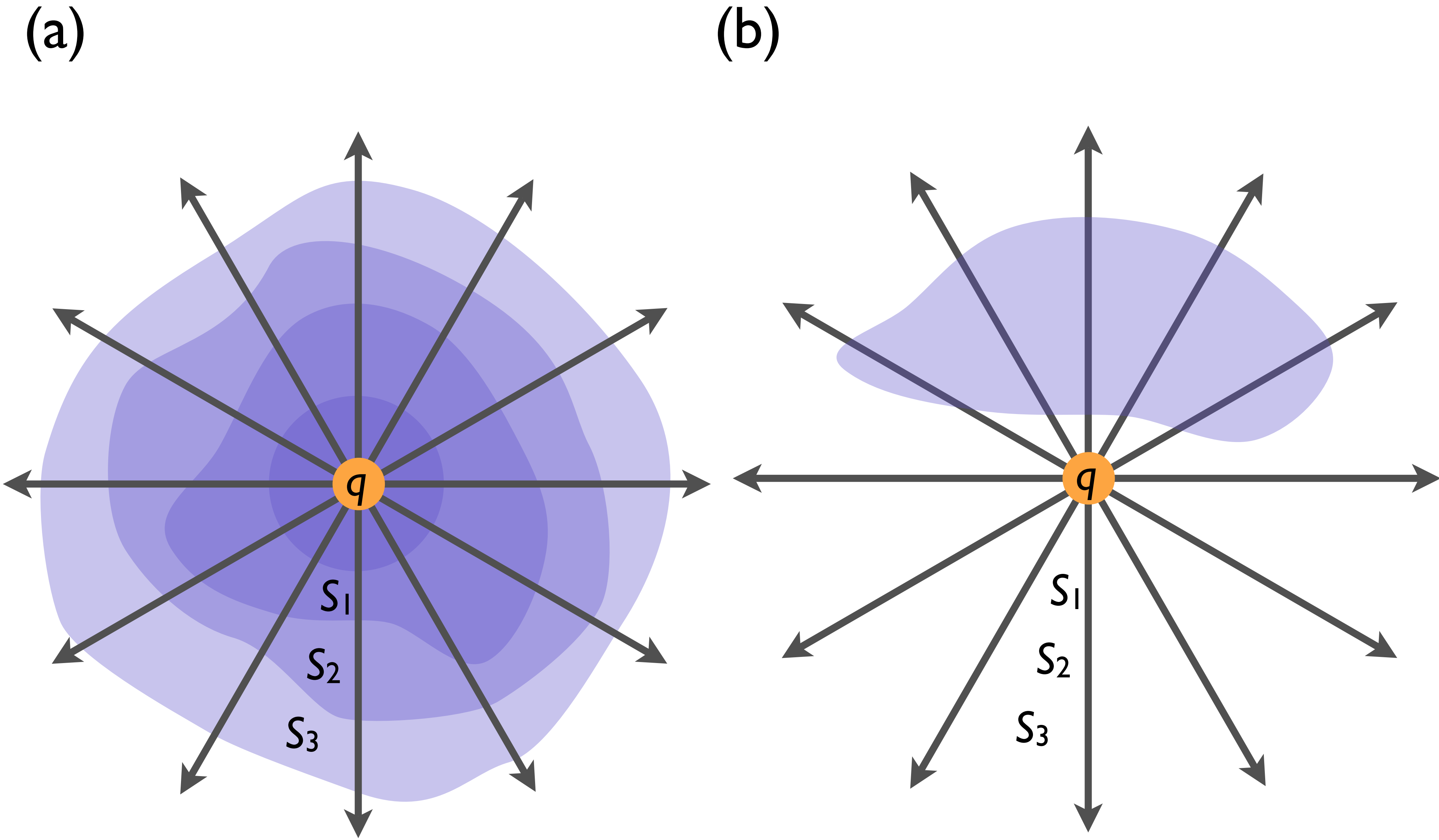

conducting
dome
B
belt
insulating
stand
A
ground



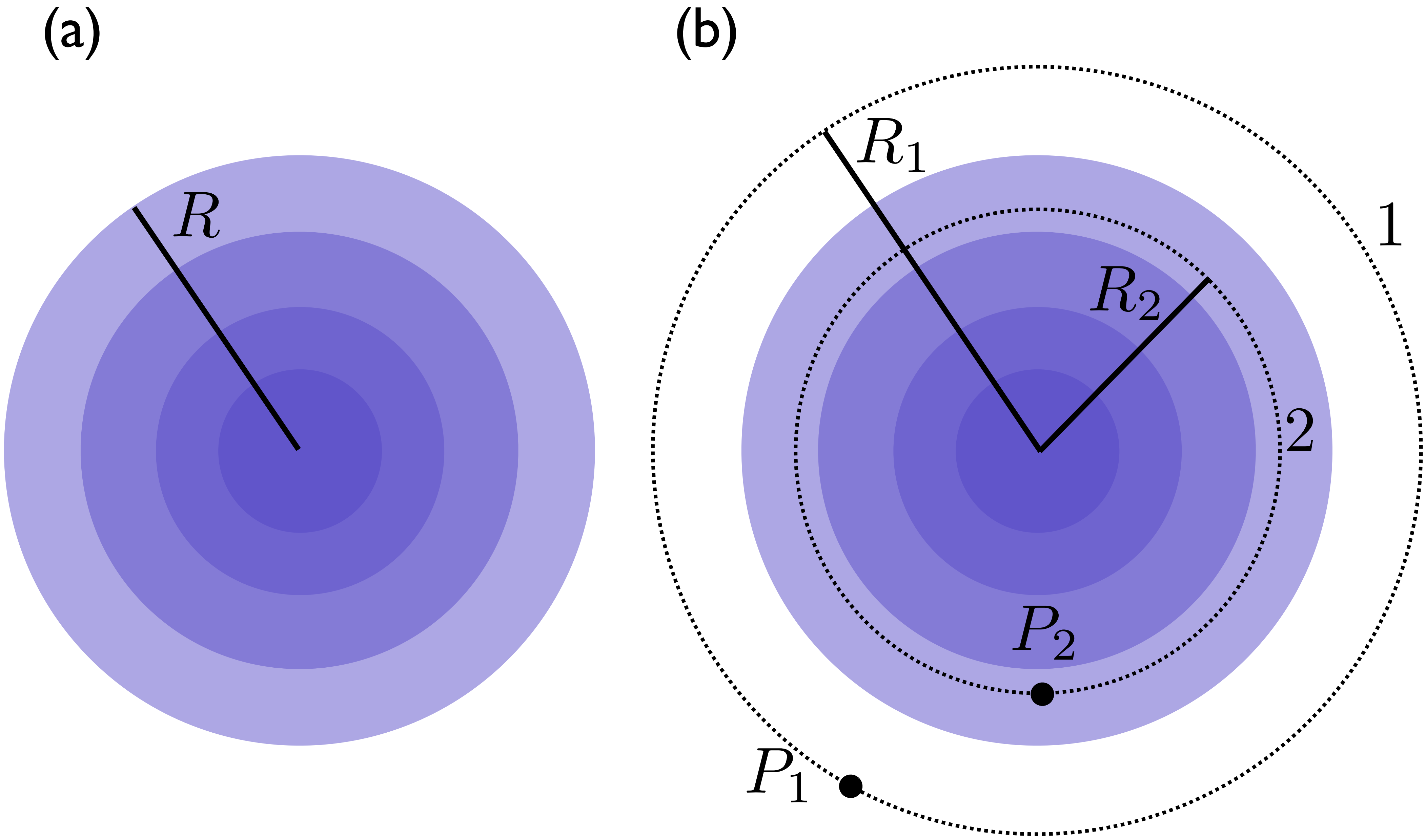


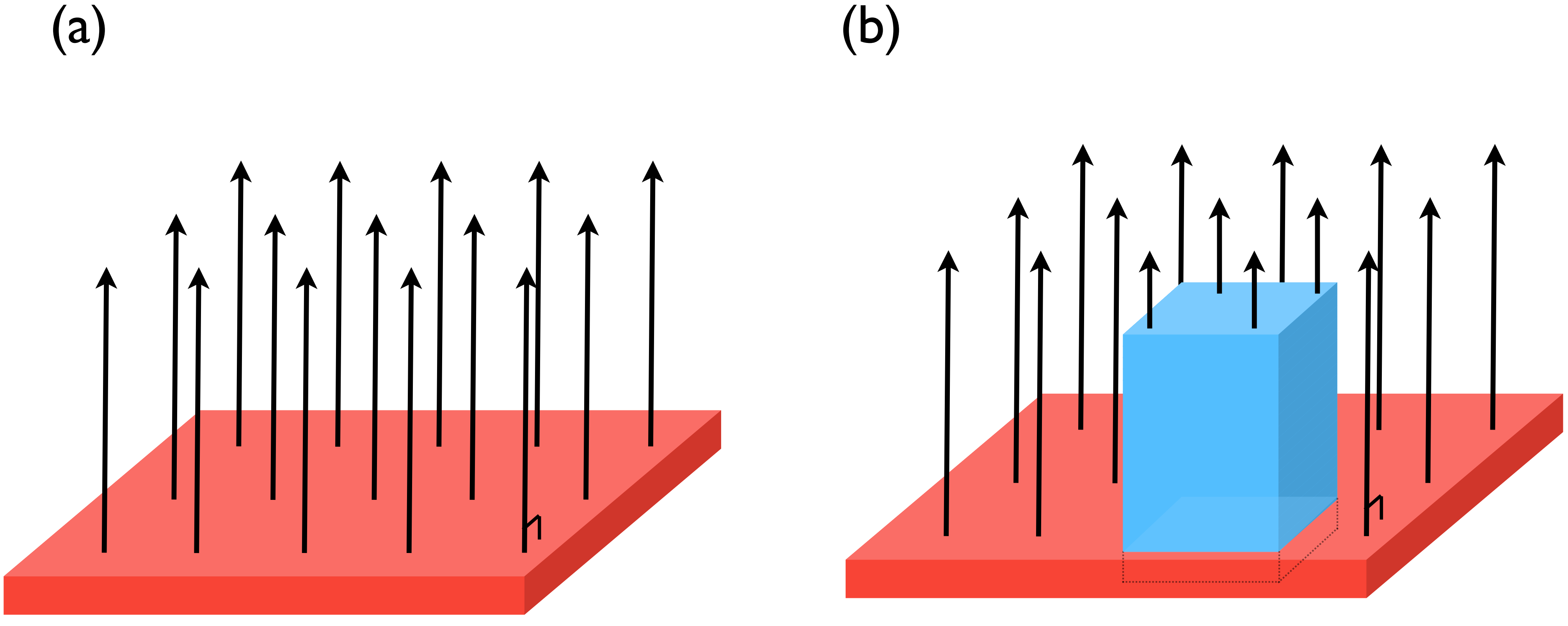


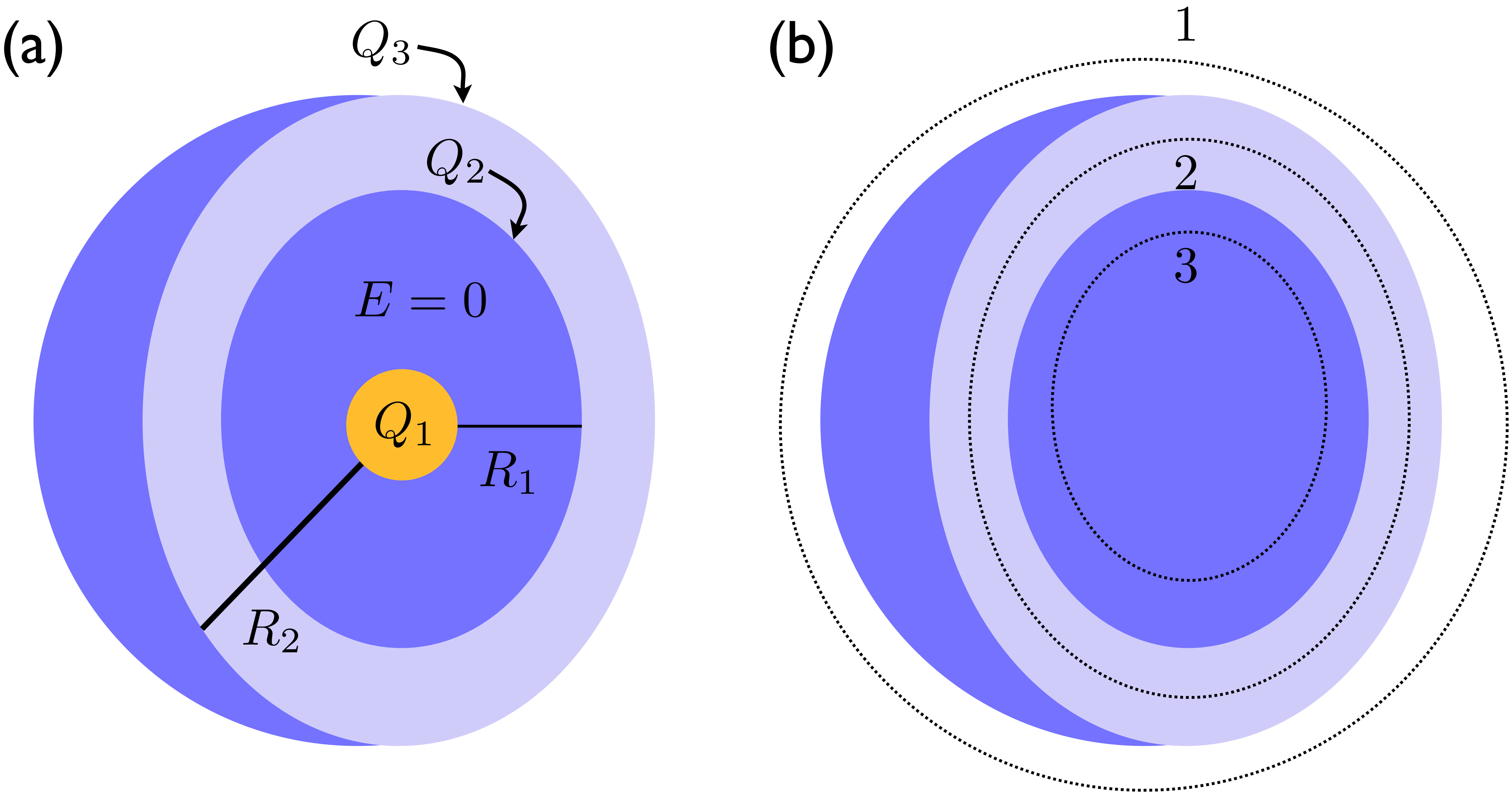
A
normal
θ
θ
E
Area = A′ = A cos θ



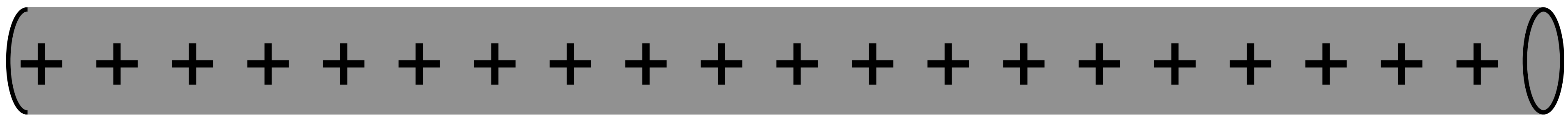
(a)
q
S_1
S_2
S_3
(b)
q
S_1
S_2
S_3


(a)
R
(b)
R1
R2
1
2
P2
P1




(a)
Q_3
Q_2
$E = 0$
Q_1
R_1
R_2
(b)
1
2
3

(a)



(b)