LECTURE 2
Ch. 22.1–2

PHY 122. COULOMB'S LAW, ELECTRIC FIELD

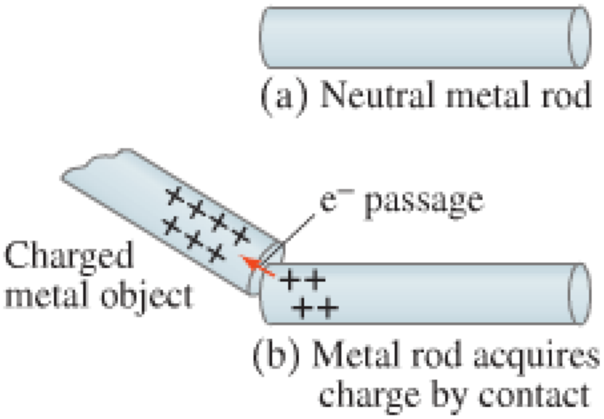
REMINDER:
- WORKSHOPS START NEXT WEEK

  FOR IMPERATIVE CHANGES IN WORKSHOPS:
  CONTACT JANET FOGG IN B&L 211

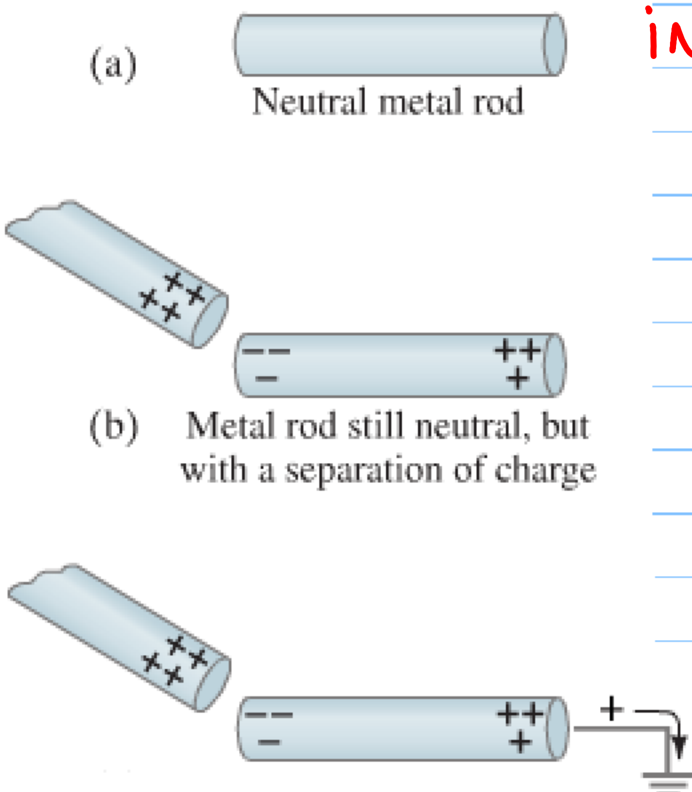
- HOMEWORK STARTS NEXT WEEK

  DEADLINE: SATURDAY 13th 5pm
  B&L MAILBOXES (ENTRANCE TUNNELS)

INDUCED CHARGE : BODIES CAN BE CHARGED BY



CONDUCTION : DIRECT CONTACT



INDUCTION : CREATE CHARGE SEPARATION

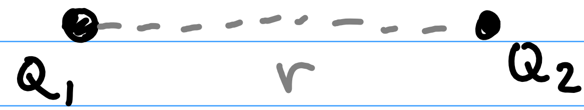
BREAK INTO PIECES

"GROUND" ONE END :

CHARGE LEAKS INTO THE EARTH

ALWAYS THINK WHERE ELECTRONS WENT. THEY ARE THE ONES TO MOVE.

COULOMB'S LAW (1785)

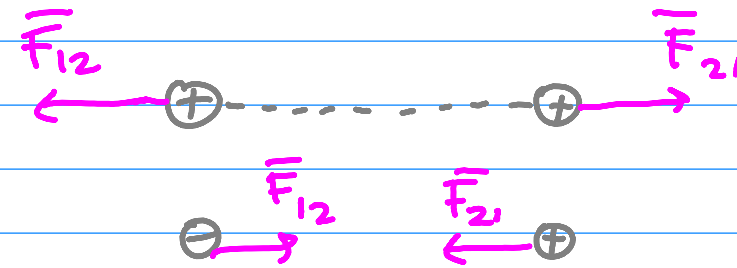


FORCE ON 1 DUE TO 2

$$\vec{F}_{12} = k \frac{Q_1 Q_2}{r^2} \hat{r}$$

UNIT VECTOR ALONG r DIRECTION

F = FORCE BETWEEN CHARGES [N]
Q = ELECTRIC CHARGE [C]
r = DISTANCE BETWEEN CHARGES [m]

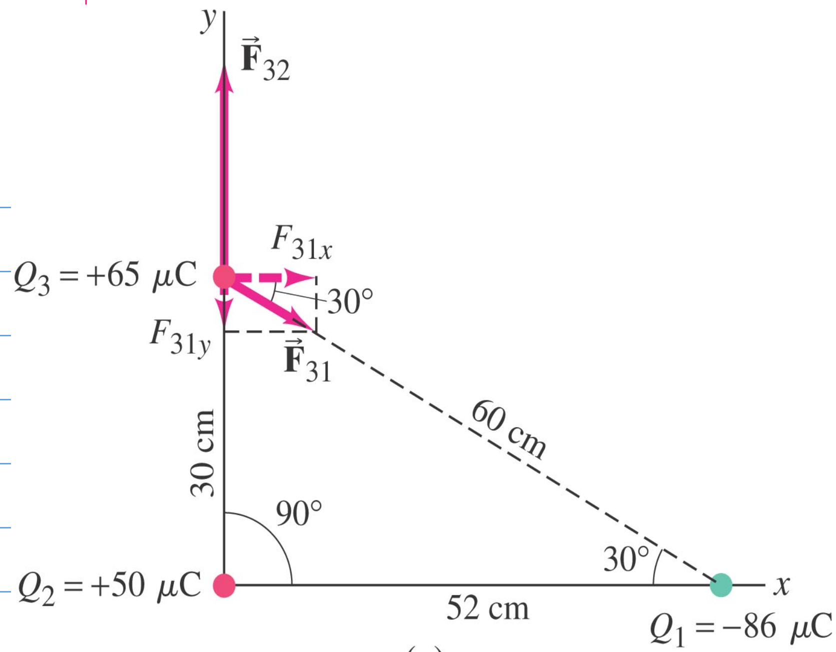


k = CONSTANT = 9×10^9 $[Nm^2/C^2]$

$k = \frac{1}{4\pi\varepsilon_0}$ $\quad \varepsilon_0$ = PERMITIVITY OF FREE SPACE = $8.85 \times 10^{-12}\ C^2/Nm^2$

IF $Q_1 \uparrow \Rightarrow F \uparrow$
IF Q_1 CHANGES SIGN $\Rightarrow$ DIRECTION OF F IS REVERSED
IF $r \uparrow \Rightarrow F \downarrow$

SAME SPATIAL DEPENCE AS GRAVITATIONAL FORCE $F = G\frac{M_1 M_2}{r^2}$
STRENGTH OF FORCE $\propto$ CHARGE AND $\propto \frac{1}{r^2}$
"CENTRAL" FORCE : ALONG LINE OF SEPARATION



(a)

Calculate the electrostatic force on object 3:

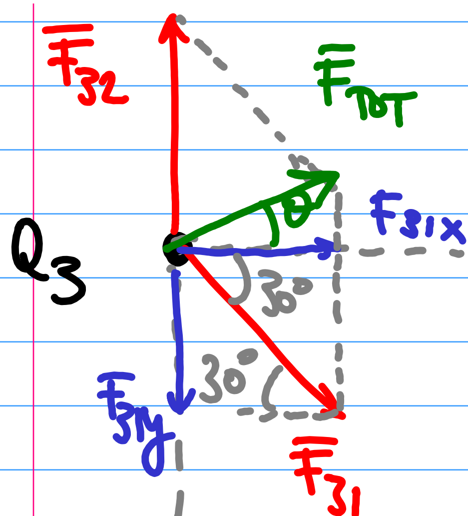
$Q_1 = -86\ \mu C$

$Q_2 = +50\ \mu C$

$Q_3 = +65\ \mu C$

$r_1 = 60\ cm = 0.6\ m$

$r_2 = 30\ cm = 0.3\ m$



$F_{31} = k\frac{Q_1 Q_3}{r_1^2} = 140\ N$

$F_{32} = 330\ N$

$F_{31}x = F_{31}\cos 30° = 120\ N$

$F_{31}y = -F_{31}\sin 30° = -70\ N$

$F_x = F_{31}x = 120\ N$

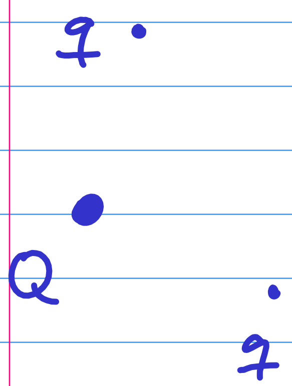
$F_y = F_{32} + F_{31y} = 330 - 70 = 260\ N$

$\Big\}\ F_{TOT} = \sqrt{F_x^2 + F_y^2} = 290\ N$

$\tan\theta = \frac{F_y}{F_x} = 2.2 \rightarrow \theta = 65°$

WHAT IF Q_3 CHANGES?

ELECTRIC FIELD



$$F = k\frac{Qq}{r^2} \rightarrow F = qE \rightarrow E = k\frac{Q}{r^2}$$

$$k\frac{Q}{r^2} = E$$

E IS THE ELECTRIC FIELD WHERE q IS, AS CREATED BY Q

Q HAS CHANGED THE PROPERTIES OF SPACE AROUND IT.
TEST CHARGE q FEELS THAT CHANGE.

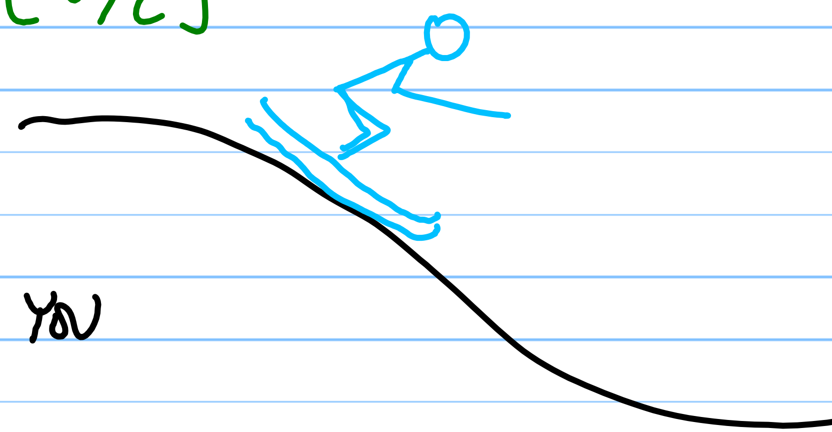
$F = qE$ THE NET COULOMB FORCE ON A GIVEN CHARGE IS ALWAYS PROPORTIONAL TO THE STRENGTH OF THAT CHARGE

E IS INDEPENDENT OF q (THE TEST CHARGE): IT ONLY DEPENDS ON POSITION IN SPACE AND THE SOURCE CHARGE Q.

ELECTRIC FIELD: $E = \frac{F}{q}$ IS THE FORCE EXERTED ON A SMALL POSITIVE TEST CHARGE q, DIVIDED BY THE MAGNITUDE OF THAT CHARGE

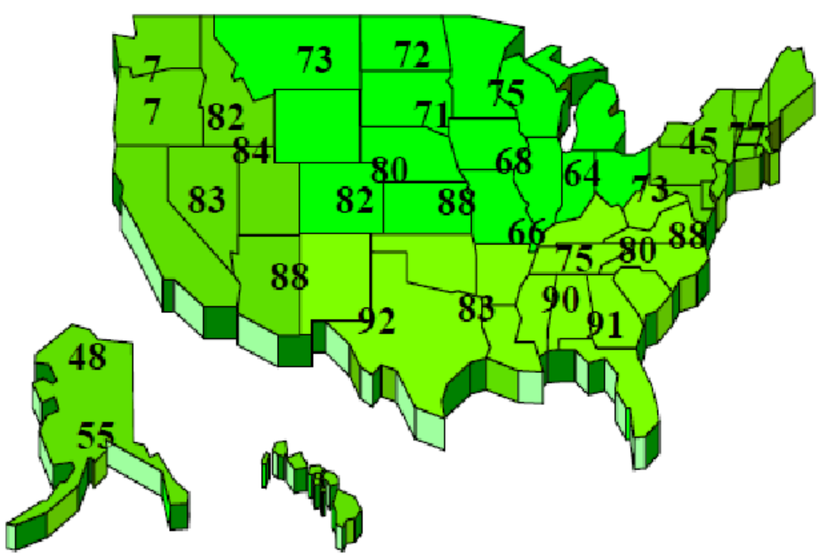
IT IS A VECTOR, MEASURED IN [N/C]

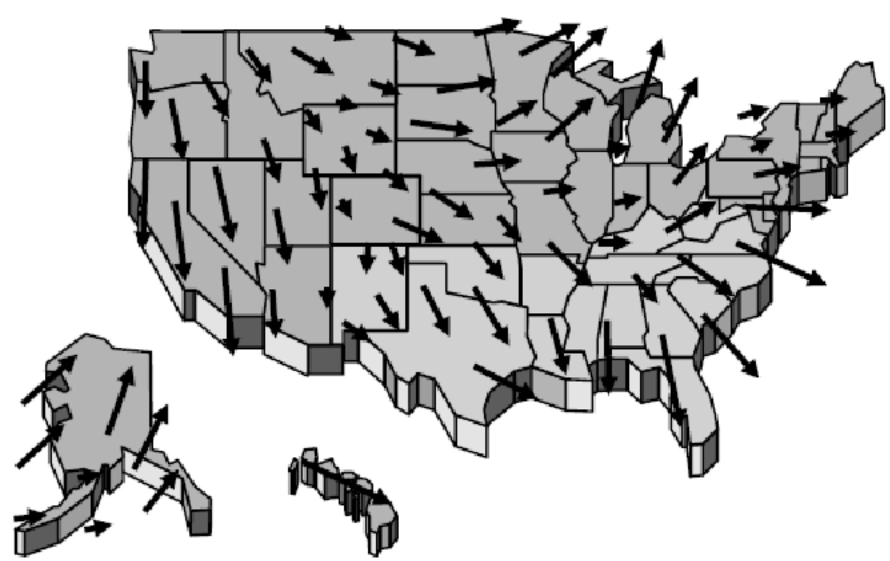
$\vec{E}$ IS LIKE A SKI SLOPE



CHARGE q : THE SKIER

THE SLOPE IS THERE WHETHER YOU SKI DOWN OR NOT.



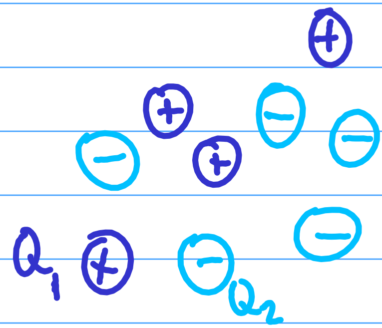


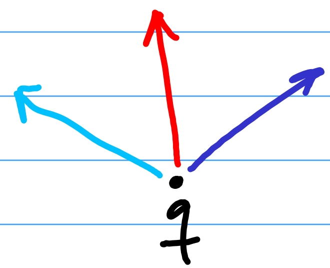
SCALAR FIELD: TEMPERATURE

VECTOR FIELD: WIND, $\vec{E}$, $\vec{g}$

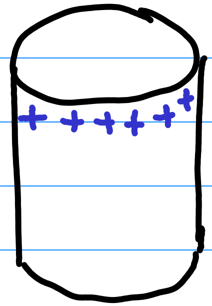
THE CONCEPT OF FIELD, ALLOWS US TO "MAP" THE FORCE A CHARGE q WOULD FEEL ANYWHERE IN SPACE, AS PRODUCED BY ANY ARBITRARY:

BUNCH OF CHARGES





CHARGE DISTRIBUTION

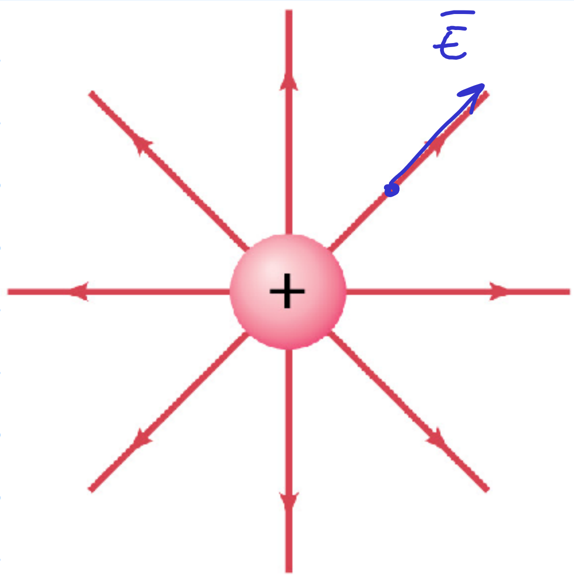


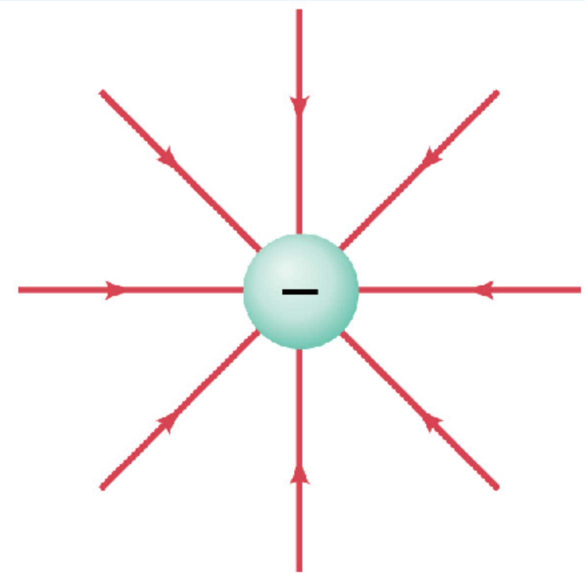
$$\bar{E} = k \sum \frac{Q_i}{r_i^2} \hat{r}_i$$

$$\bar{E} = k \int \frac{dQ}{r^2} dr$$

SUPERPOSITION: NET FIELD IS THE VECTOR SUM OF ALL FIELDS

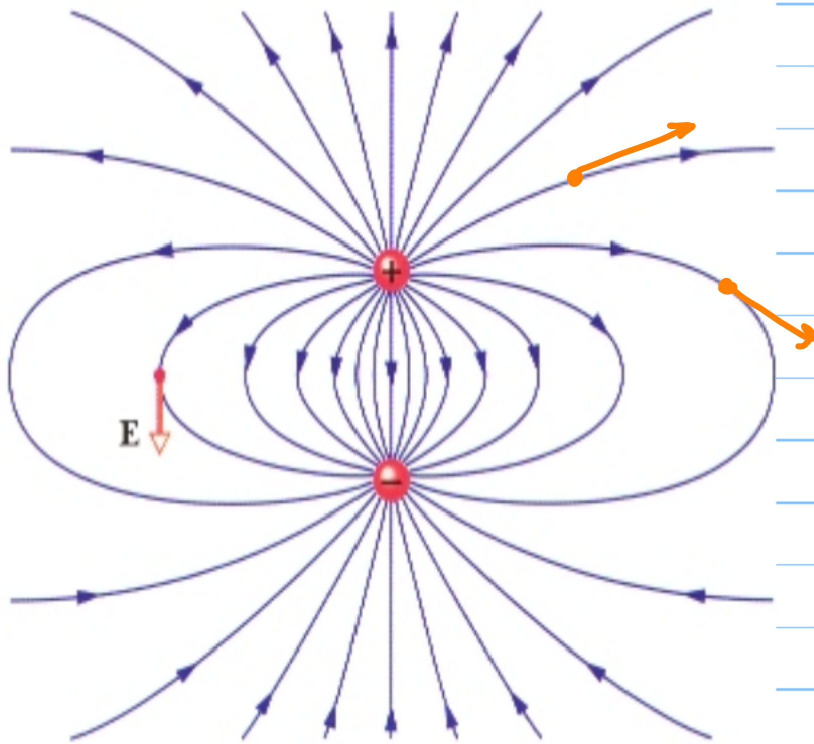
VISUALIZATION TOOL : FIELD LINES





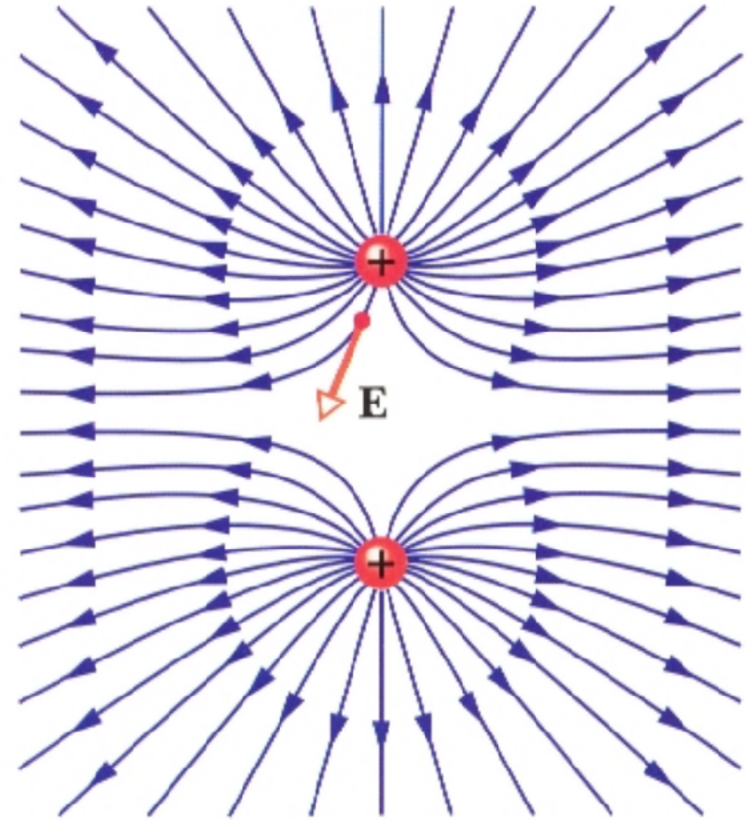
- LINES LEAVE POSITIVE CHARGES AND RETURN TO NEGATIVE CHARGES
- NUMBER OF LINES LEAVING/ENTERING CHARGE IS PROPORTIONAL TO THE AMOUNT OF CHARGE
- DIRECTION OF $\bar{E}$ IS TANGENT TO THE LINES

OTHER CONFIGURATIONS



- LINES NEVER CROSS
- CAN BE OPEN
- DENSITY OF LINES REPRESENTS THE INTENSITY OF $\bar{E}$

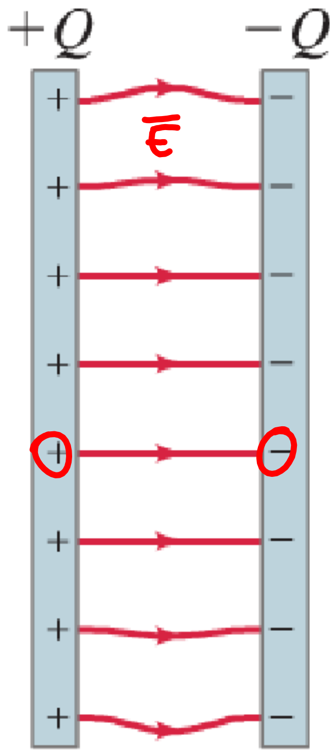
DIPOLE

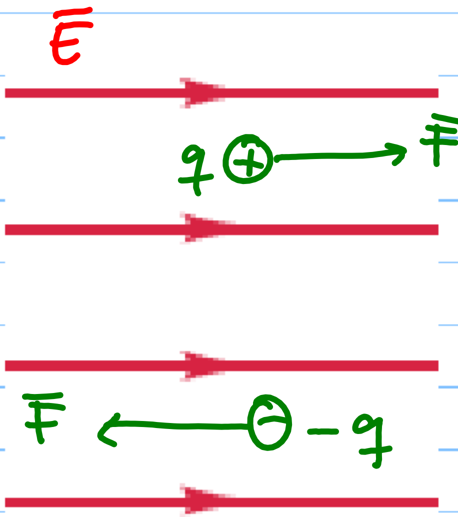


- THERE IS A ZERO HALFWAY BETWEEN THE TWO CHARGES
- $r \gg L$: LOOKS LIKE THE FIELD OF A POINT CHARGE $+2Q$ AT THE ORIGIN.

CONSTANT STATIC FIELD

$$\vec{F} = q\vec{E}$$

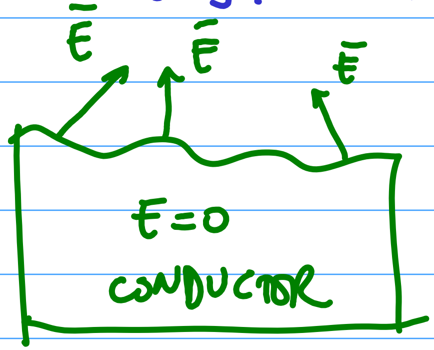




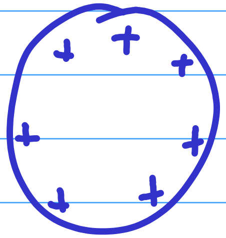
$\vec{E}$ FIELD IS CONSTANT BETWEEN TWO VERY LARGE PARALLEL PLATES.

$\vec{E}$ FIELD IN CONDUCTORS

CONDUCTORS: MATERIAL WITH ABUNDANT FREE (TO MOVE) e^-



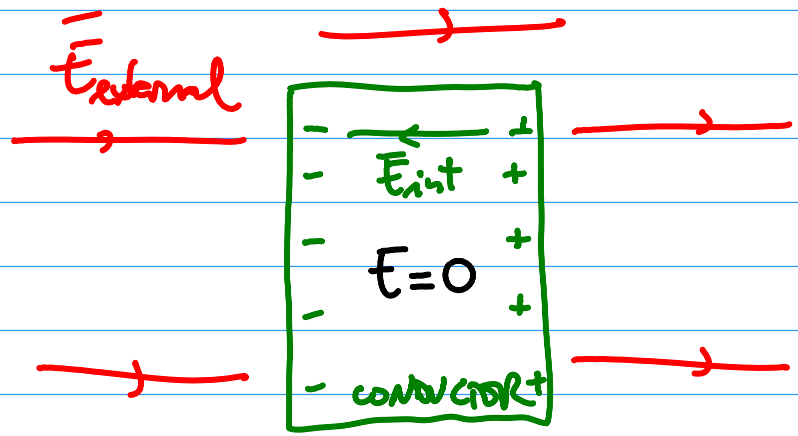
- $\bar{E}$ MUST VANISH INSIDE A CONDUCTOR
- IT MUST ALSO BE PERPENDICULAR TO CONDUCTOR AT THE SURFACE.



IF THE CONDUCTOR IS CHARGED:

- CHARGE ACCUMULATES ON SURFACE
- LIKE-CHARGES REPEL: MAX. POSSIBLE SEPARATION

CONDUCTOR IN AN EXTERNAL E FIELD:



$E=0$ INSIDE CONDUCTORS IN A STATIC SITUATION

E IS PERPENDICULAR TO THE SURFACE

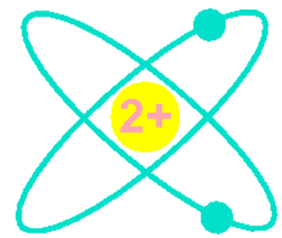
$$\bar{E}_{inside} = \bar{E}_{ext} + \bar{E}_{int} = 0$$

METAL HOLLOW BOXES ARE USED TO SHIELD ELECTRIC FIELDS.

Charge is electrons and ions, what is a conductor?

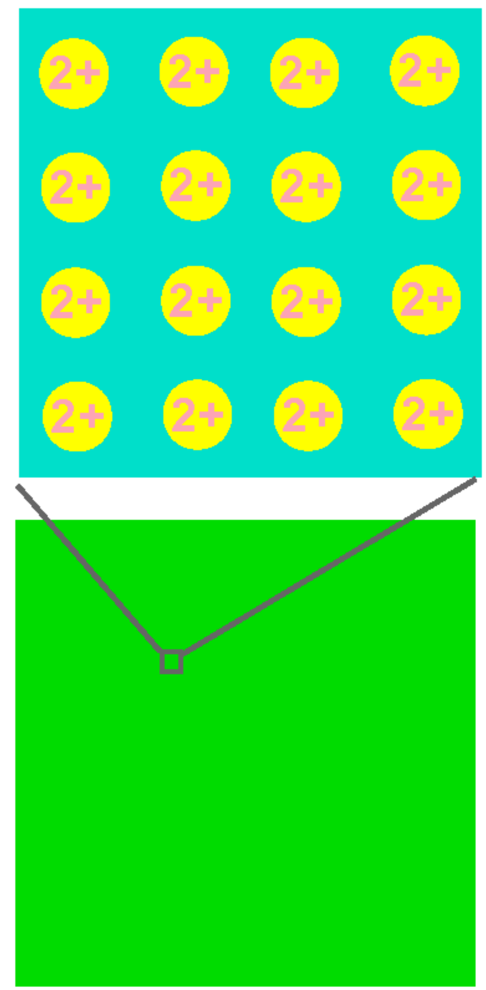
A two electron atom, e.g. Ca

- **heavy ion core**
- **two valence electrons**



An array of these atoms

- **microscopically crystalline**
- **ions are immobile**
- **electrons can move easily in response to a field**

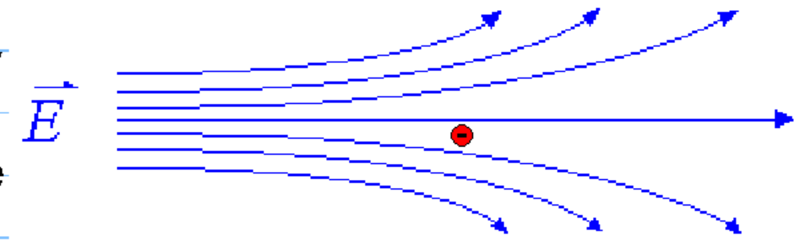


Viewed macroscopically:

- **neutral**

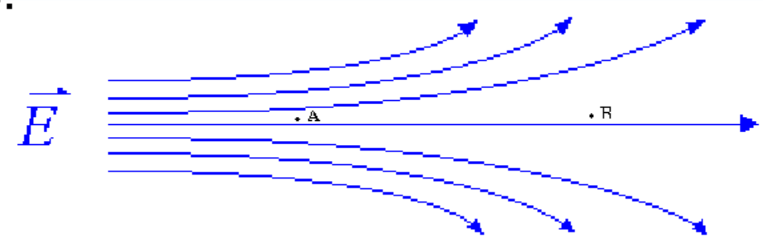
Quiz 2

- 2.1 A negative charge is placed in a region of electric field as shown in the picture. Which way does it move?



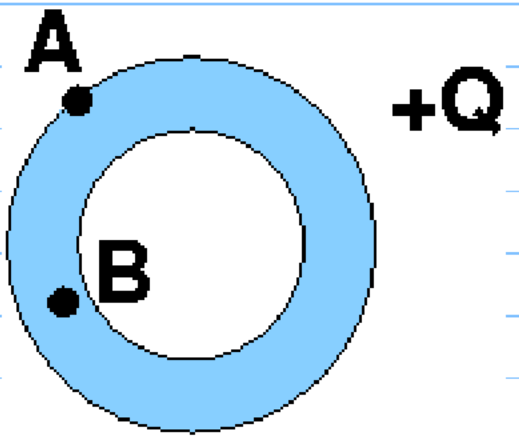
a) up b) down c) left d) right e) doesn't move

- 2.2 Compare the field strengths at points A and B.



a) $E_A>E_B$ b) $E_A=E_B$ c) $E_A>E_B$

- 2.3 A hollow conducting sphere has a net charge +Q. Which of the following statements correctly describes the electric field in the vicinity of the sphere?

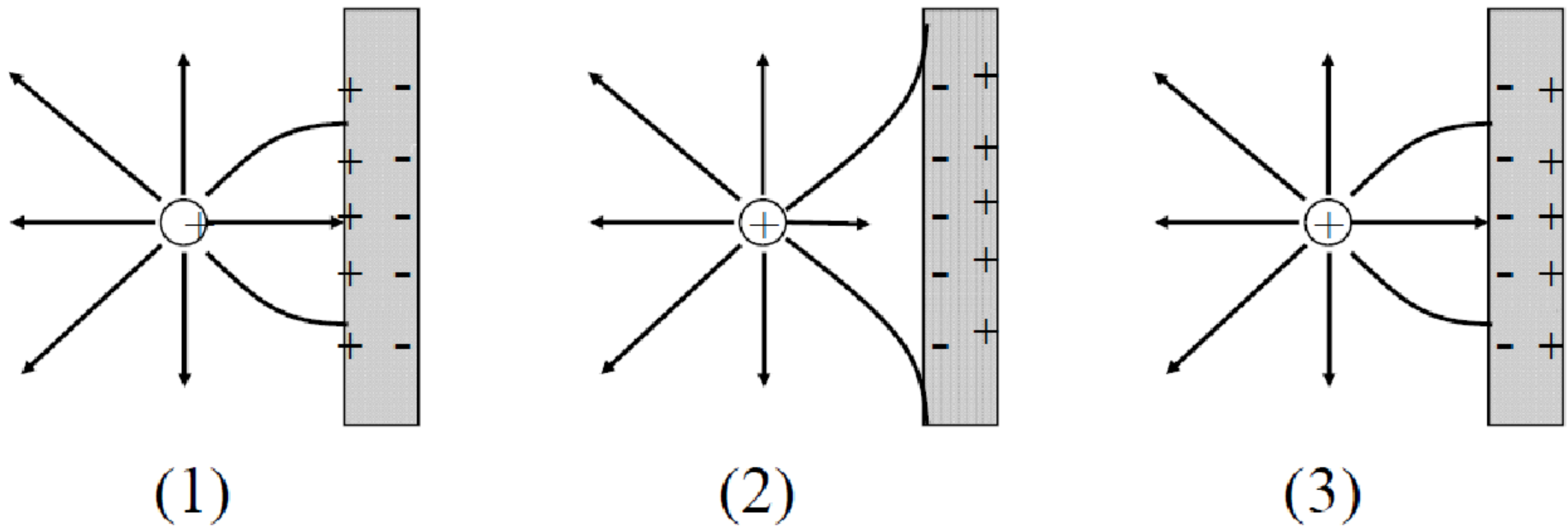


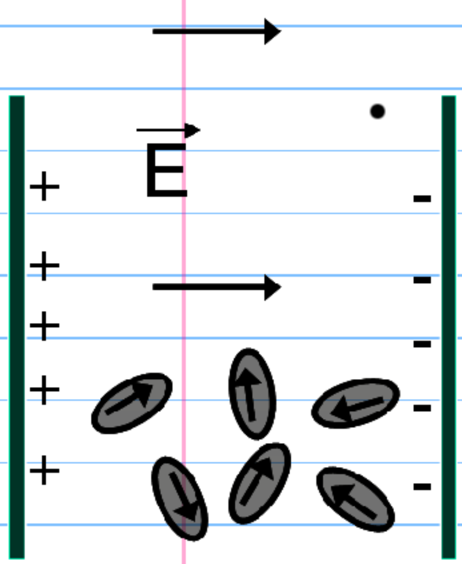
a) The magnitude of the field B is greater than the magnitude of the field at A

b) The electric field at B points towards the center of the sphere

c) The component of the electric field at A tangential to the surface of the sphere is zero

2.4 A point charge is located near a conducting plate. Choose the figure that best represents the field lines and charge configuration of the conductor





- 2.5 Polar molecules, like water, have small dipole moments. A region of electric field is created by giving equal and opposite charges to two parallel conducting plates. If this region is filled with pure water (an excellent insulator), does the electric field…

  a) Increase b) Decrease c) Stay the same

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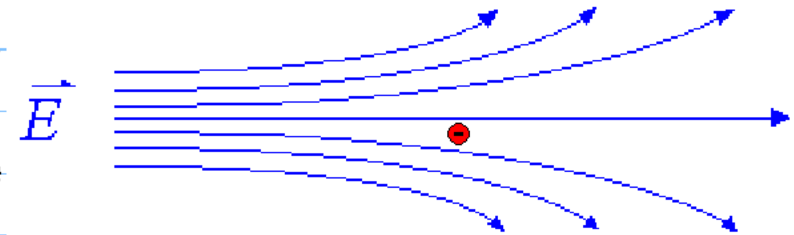

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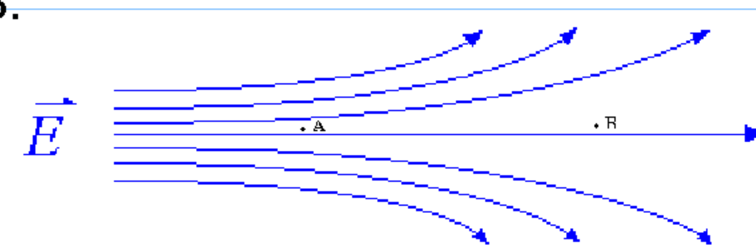

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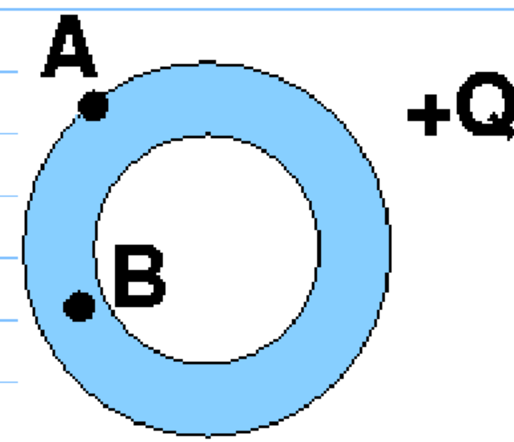

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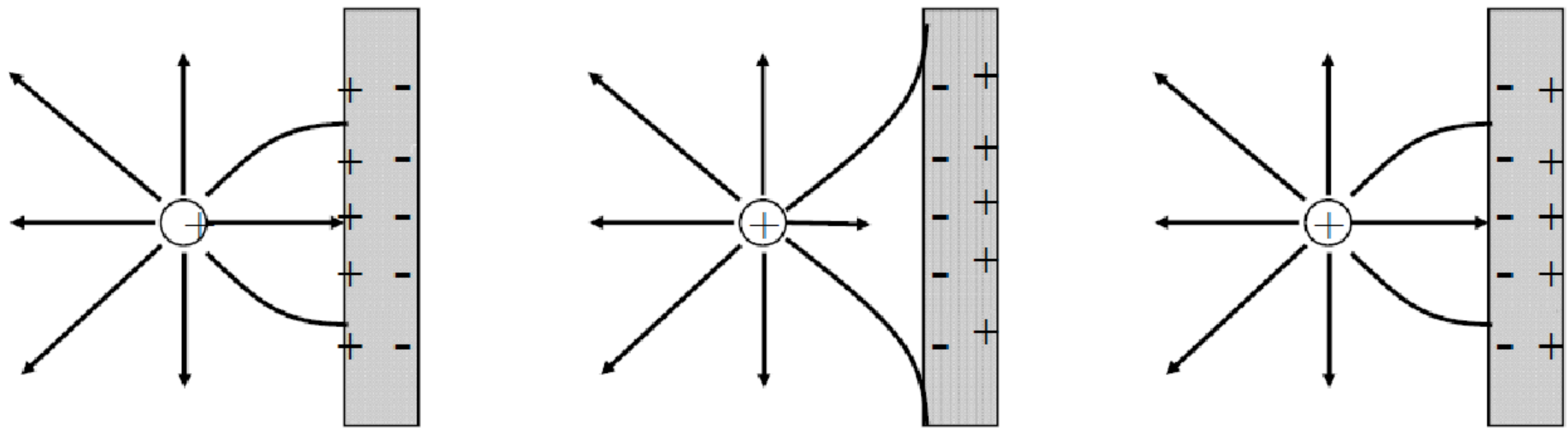
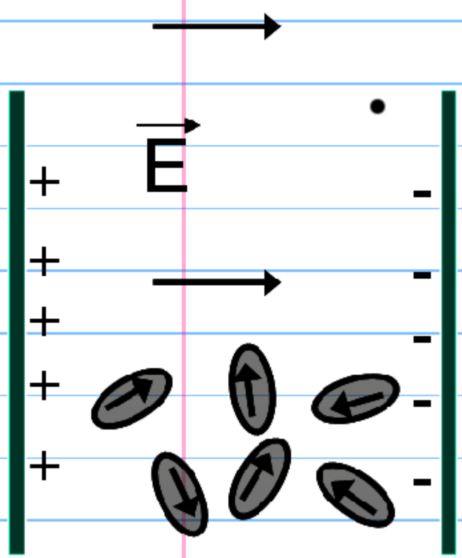


(1) (2) (3)



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