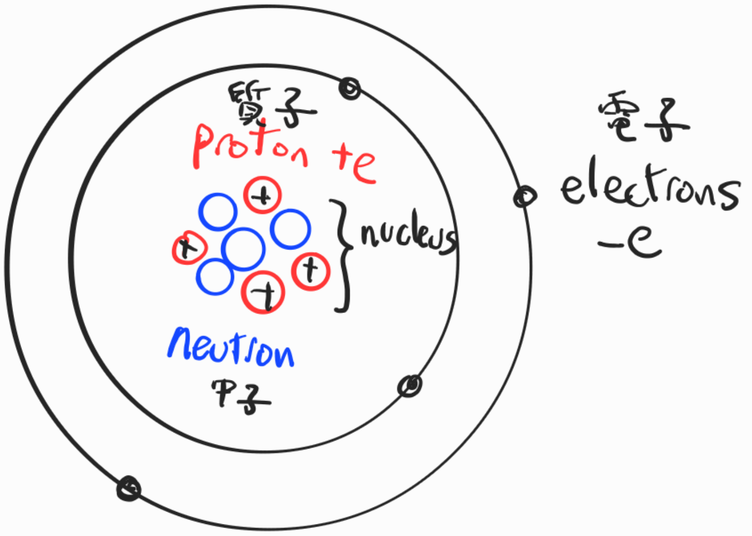
4.1 Electrostatics (Electricity + Magnetism)

靜電學

Positive Charge + + + +
Negative Charge − − − −

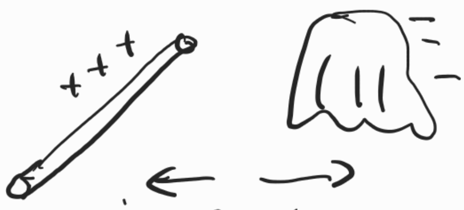
} opposite sign charge attracts
} same sign charge repels



Initially, if material is neutral, then

* losing one electron, becomes +Q

* gaining one electron becomes −Q



* net charge of an isolated system stays the same

proton $+1.6 \times 10^{-19}$ C

electron -1.6×10^{-19} C

how many electrons give 1 C? $\frac{1\text{ C}}{1.6 \times 10^{-19}\text{ C}}$

導電體

SOLID : Conductors (metal) : charges move freely

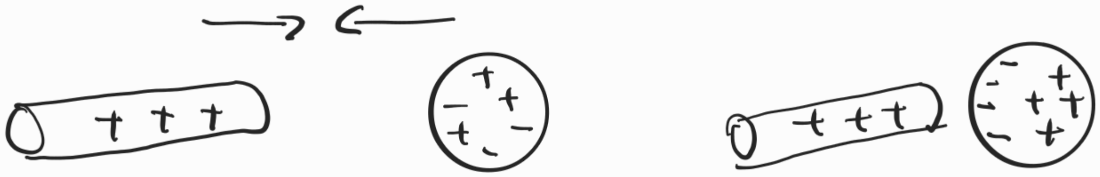
insulators (plastic) : charges cannot move freely

絕緣體

LIQUID : Conductors e.g. salt water $Na^+ Cl^- + H_2O$

insulators e.g. distilled water H_2O only

Reaction between Chaged and Neutral objects



+ve charge

neutral

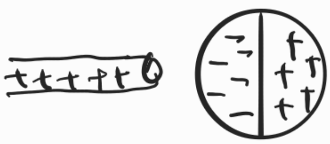
negative charges move to left

* charge on an object redistributes under the influence of another charged object nearby

step 1

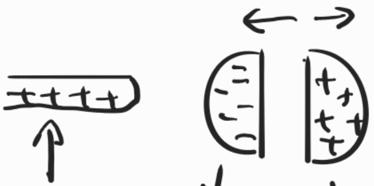
neutral 2 half ball, attached

step 2



bring close to a +ve charged rod

step 3



+ve

-ve

+ve

split the ball. Half +ve Half -ve

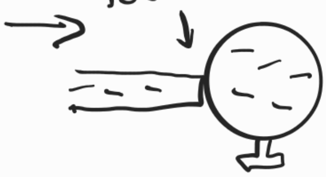
step 1

a lot of negative charge

Neutral balanced +ve, -ve charge

insulator stand

step 2



touch

negatie charge goes to ball

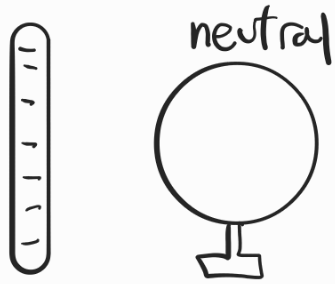
step 3

ball negative charged

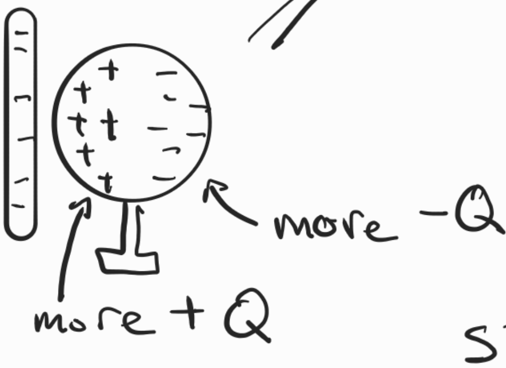
Earthing 接地

earth symbol

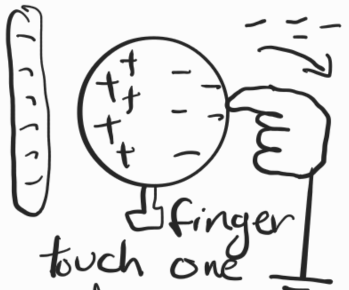
Step 1



step 2

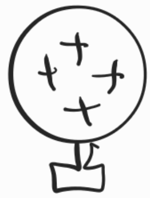


step 3



touch one side, leak −Q to earth

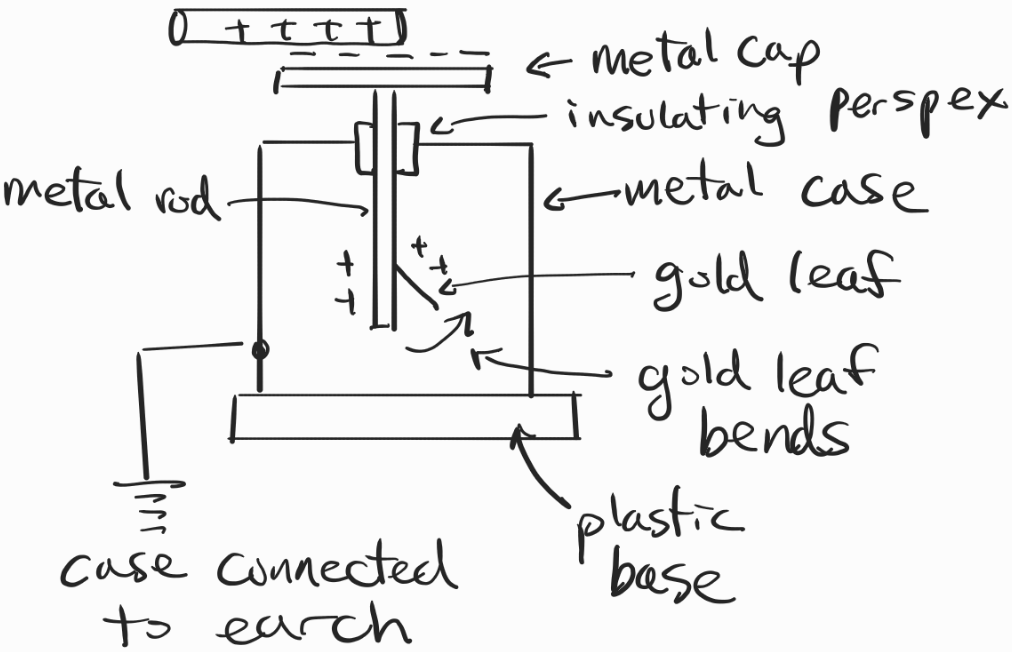
step 4



take away finger + rod
ball is positively charged

Gold Leaf Electroscope

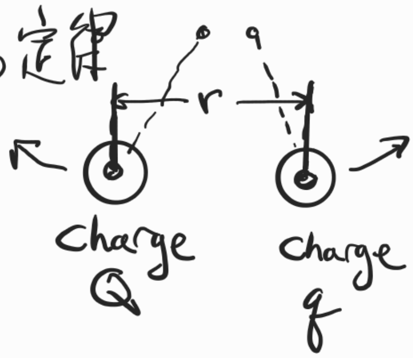
when gold leaf bends upward, it is +ve charged



Electric force

Coulomb's Law : $F = k \times \dfrac{Qq}{r^2}$

庫倫定律



F ↑ force between Q and q

Qq ← proportional to F

r^2 ↑ inverse square to F

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{Qq}{r^2}$$

Qq → 2 spheres with uniform distribution

ε_0 : permittivity of free space

vacuum	: ε_0
air	: ε_0
Perspex	: $2.76\,\varepsilon_0$
water	: $7.12\,\varepsilon_0$

Electric Field Strength 電場 (E)

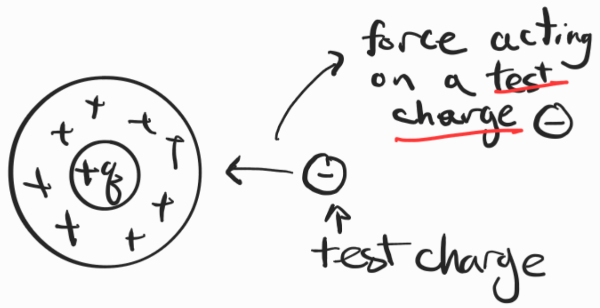
注意：test charge small value

$$F = qE$$

F ↑ force on the charge +q

q ↙ amount of the charge

E ↑ force per unit charge +q experiences



or

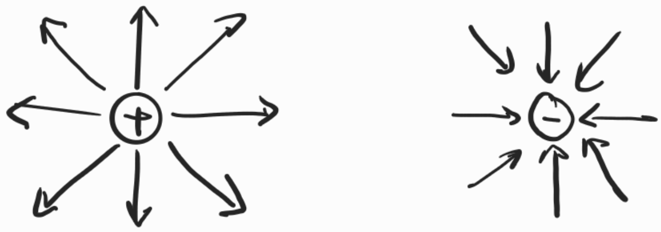
$$\boxed{E = F/q \Rightarrow \underbrace{\frac{N}{C} \text{ or } NC^{-1}}_{\text{unit}}}$$

unit of E : NC^{-1}

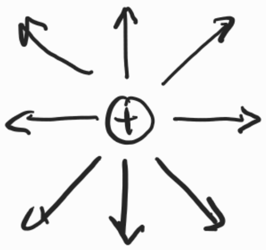
Electric Field Patterns

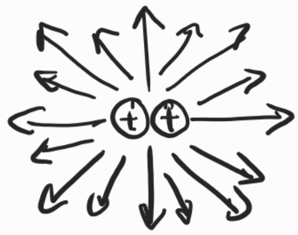
imaginary lines to represent electric field lines

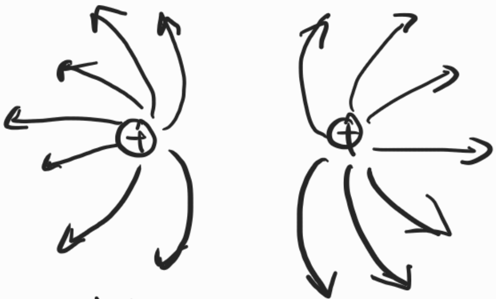
Point source



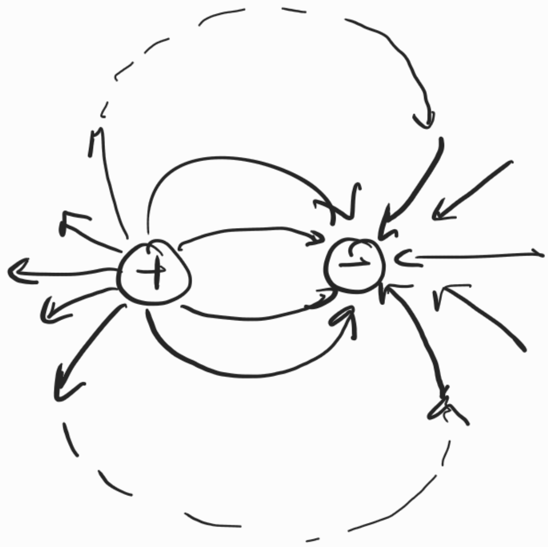
Typical Patterns (point source)



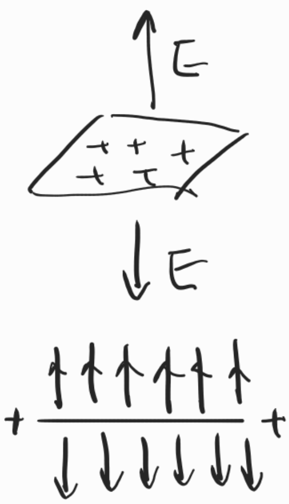


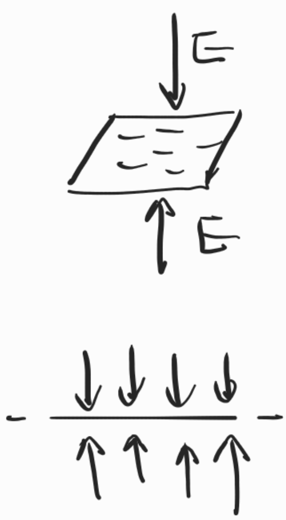


like charge repels

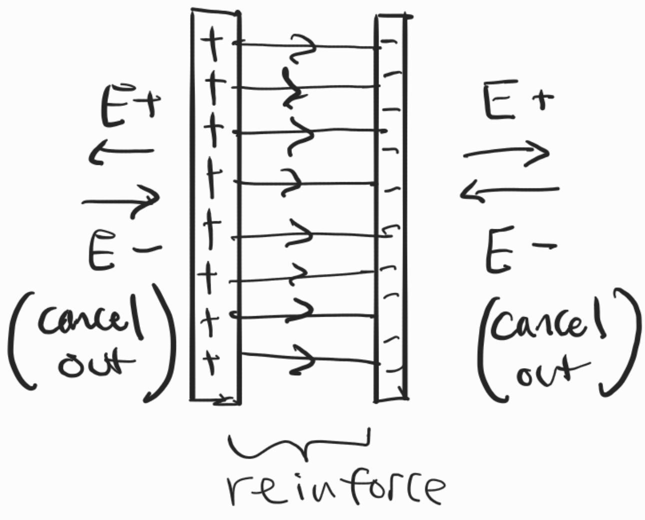


Typical Patterns (plates)



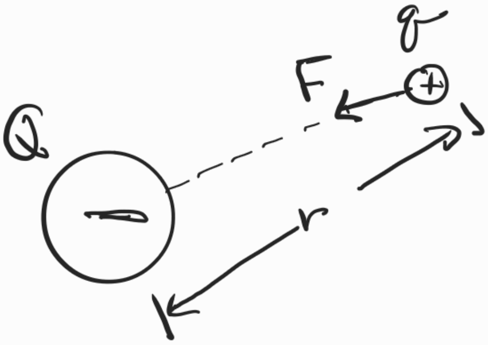


$\vec{E} = \vec{E}_+ + \vec{E}_-$



Formulae for electric field

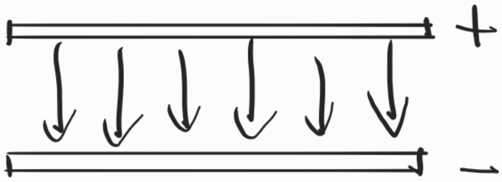
$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2}$$



E : Electric Field
電場

$$E = \frac{F}{q} = \frac{V}{d} \quad \text{(parallel plates)}$$

$V = Ed$



E : electric field strength

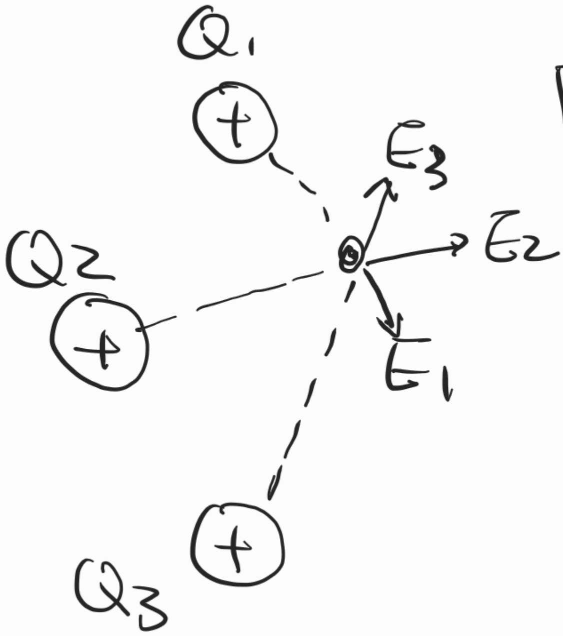
F : force btw plates

q : charge

V : applied voltage

d : distance btw plates

Many Point Charges



$$F = F_1 + F_2 + \cdots$$

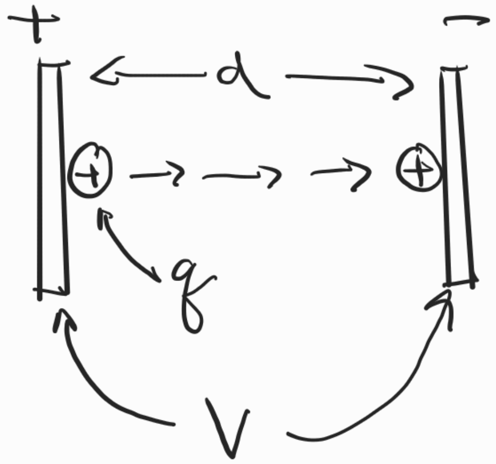
$$= qE_1 + qE_2 + \cdots$$

$$= q(\underbrace{E_1 + E_2 + \cdots}_{\text{vector sum}})$$

Work done by electric field

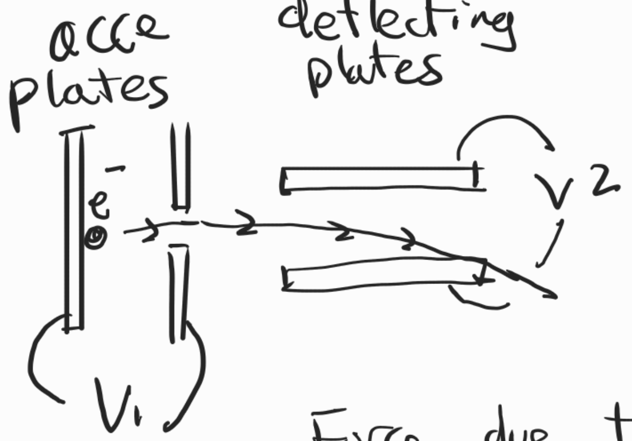
KE : Kinetic Energy

$$\Delta KE = \text{work done}$$
$$= \text{force} \times \text{distance}$$
$$= qE \times d$$
$$= qV$$



The voltage across the gap is equal to the work per unit chage by the test charge moving across the gap.

electron gun



ΔKE (accelerate plates)

$$\frac{1}{2}mv^2 - 0 = qV_1$$
$$\frac{1}{2}mv^2 = qV_1$$

Force due to deflecting plates

$$F = qE = q\frac{V_2}{d} = ma$$

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