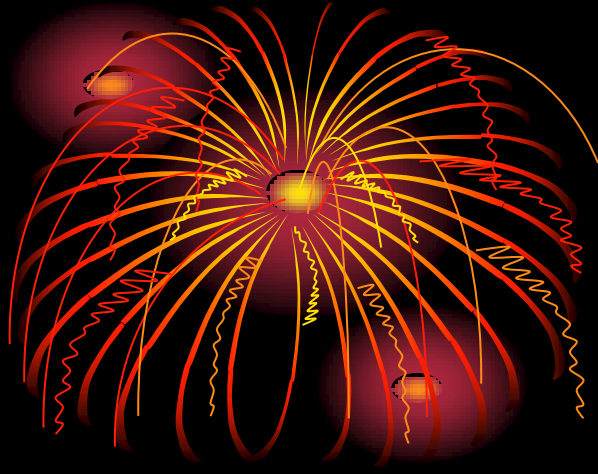
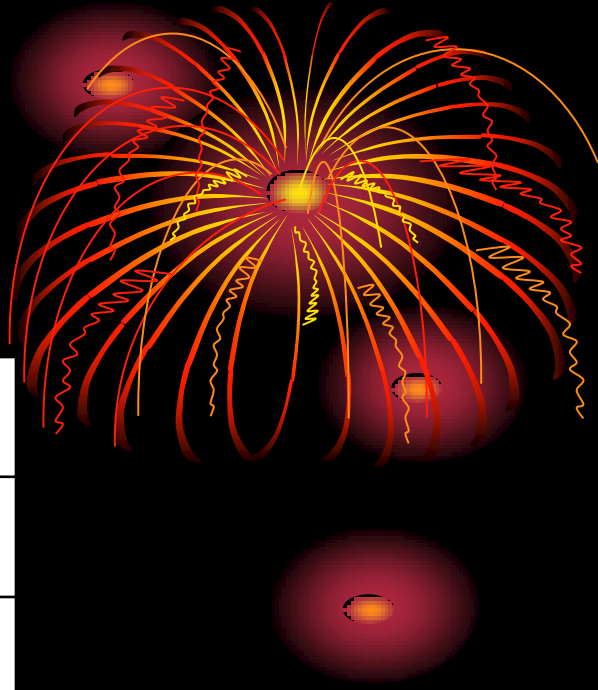
102學年上學期高二物理

黃信健



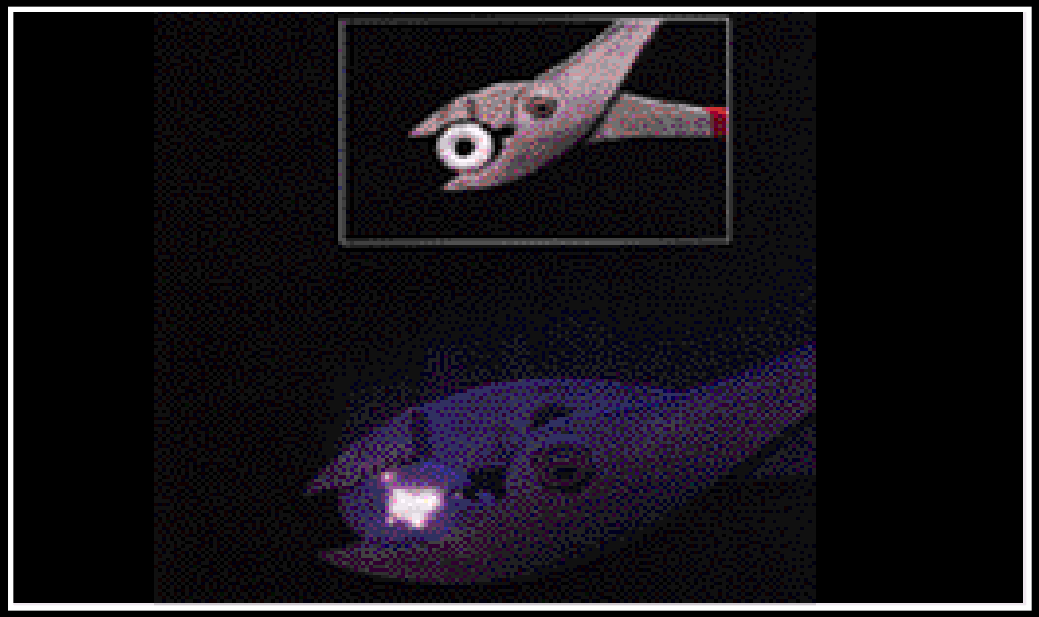
電磁學、光學與量子物理

課程表



日期	內容
2013/10/19 (一)	1電荷、靜電的應用
2013/11/02 (二、三)	2 電力與電場
2013/11/16 (四)	3高斯定律
2013/11/30 (五)	4電位
2013/12/14 (六)	5電容
201312/28 (七)	6電流與電阻
2013/01/11 (八)	7電路

電磁學



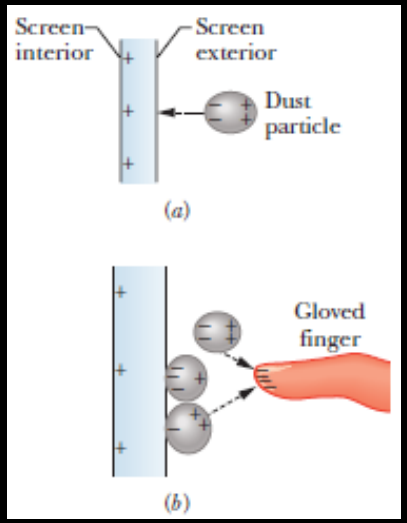
What causes the “sparking” of a wintergreen lifesaver?

電磁學

Hospital personnel go to extraordinary lengths to avoid bacterial infection of a patient. Surfaces are scrubbed, masks are donned, hands are meticulously cleaned and then gloved, and instruments are sanitized at high temperature and in alcohol baths. But there are still subtle sources of bacteria, such as possibly in this photograph.

Can you find the bacterial source?

The answer is in this chapter.

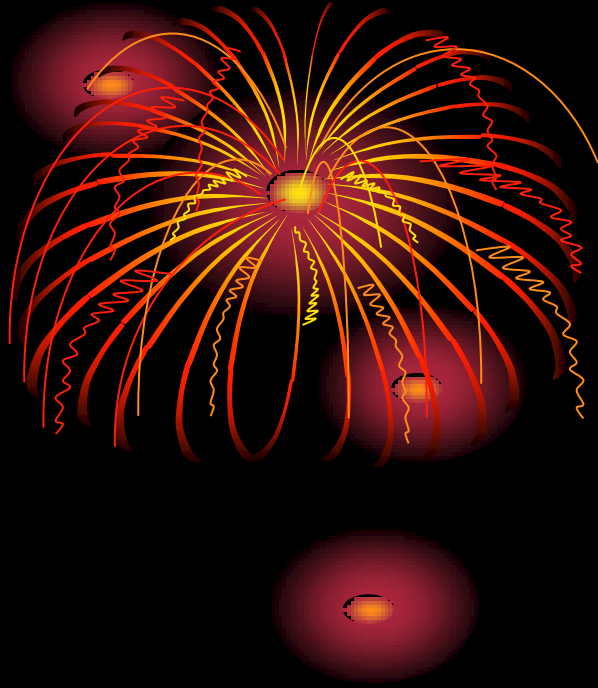


電磁學 (Electromagnetism)

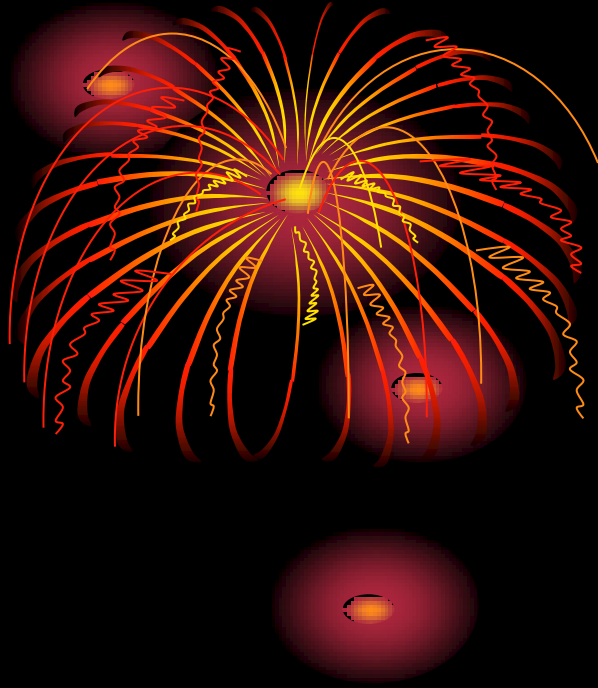
電學（Electricity）

1. 電荷
2. 電場
3. 高斯定律
4. 電位
5. 電容
6. 電流與電阻
7. 電路

磁學 (Magnetism)



8. 電流與磁場
9. 電磁感應
10. 物質的磁性
11. 反射、折射、干涉、繞射
12 量子物理



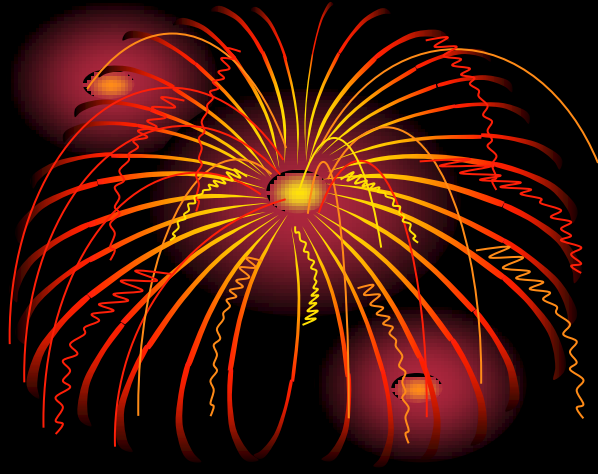
1-1 電荷、電力與電場

1.1 電荷（electric charge）

1.2 庫倫定律(Coulomb’s law)

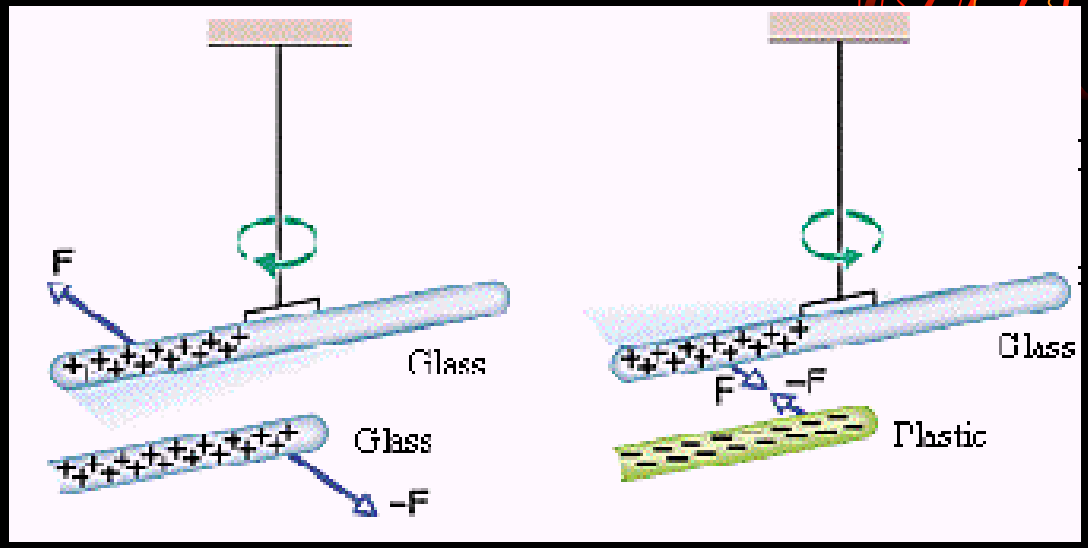
1.3 靜電的應用

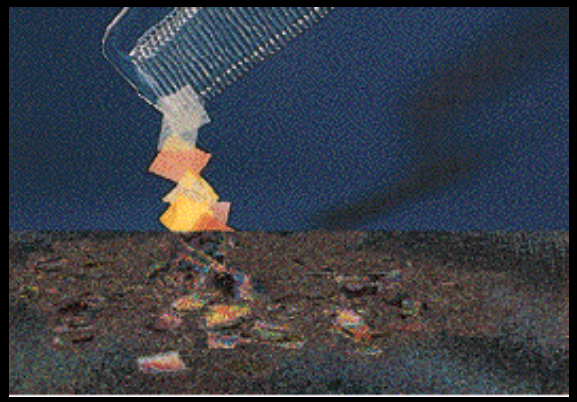
1.1 電荷



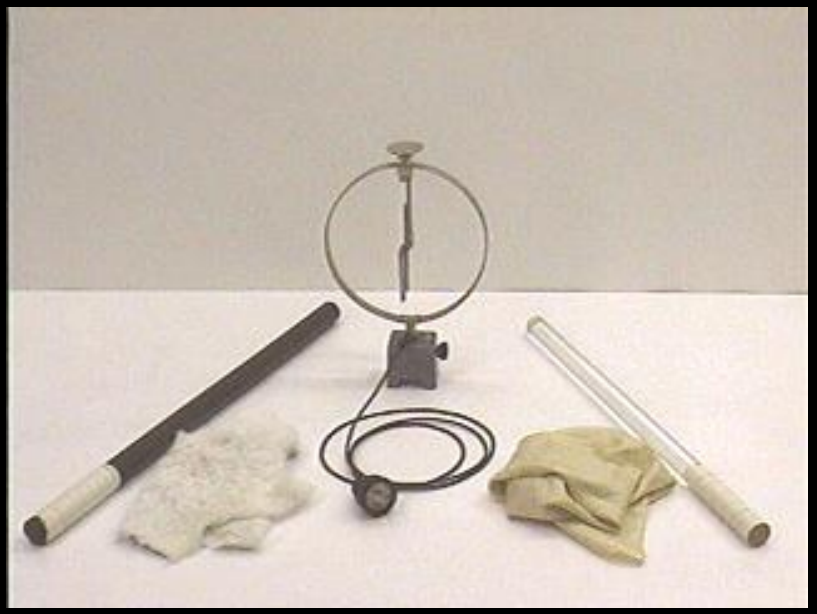
- 摩擦充電
- 塑膠棒（負荷電）與毛皮（正荷電）
- 玻璃棒（正荷電）與絲綢（負荷電）
- 感應充電

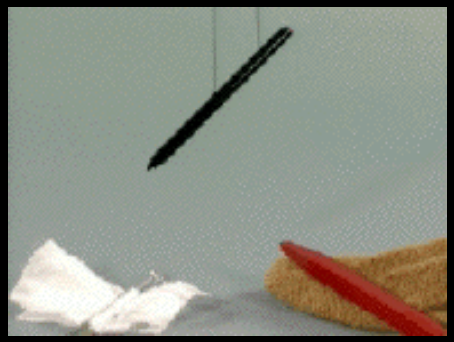
正荷電與負荷電



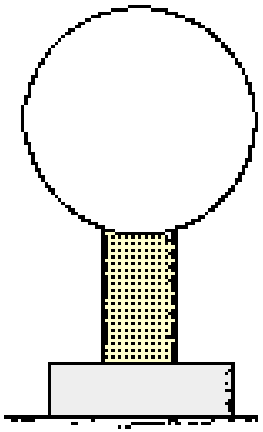


摩擦充電



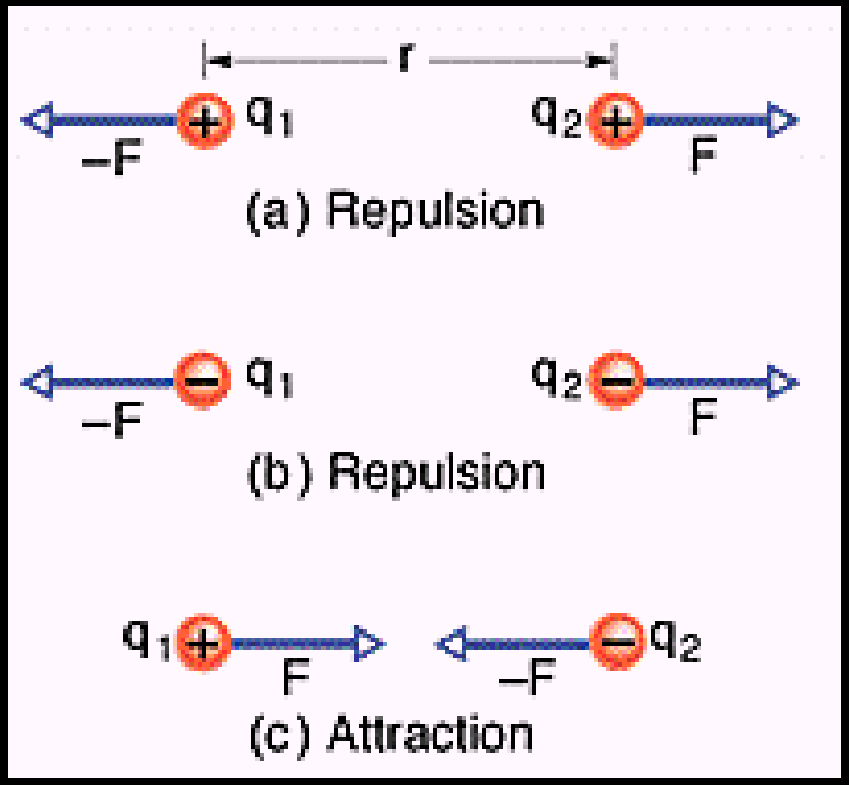


感應充電



A negatively charged object is brought near to a neutral, conducting sphere. Electrons in the sphere are forced from the left side of the sphere to the right side.

The Electric Interaction



Charge is quantized

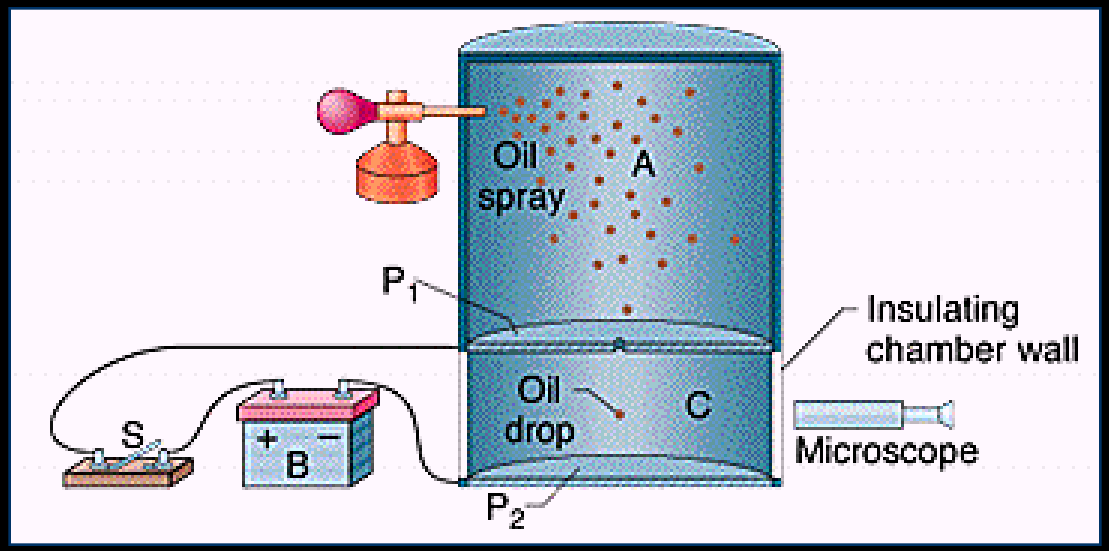
- The electric charge (e) is discrete (quantized)

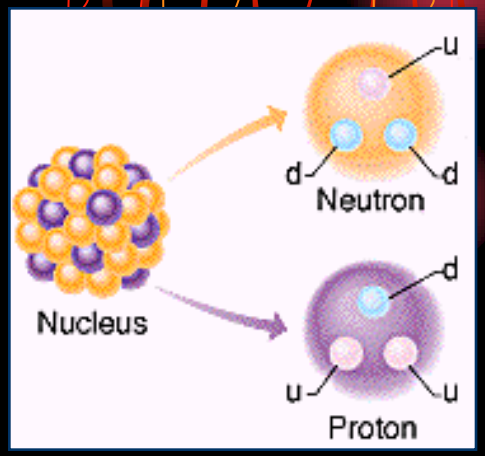
$$q = ne, n = \pm 1, \pm 2, \pm 3, \ldots$$

$$e = 1.6 \times 10^{-19} C$$

- SI unit: coulomb (C), defined in term of ampere

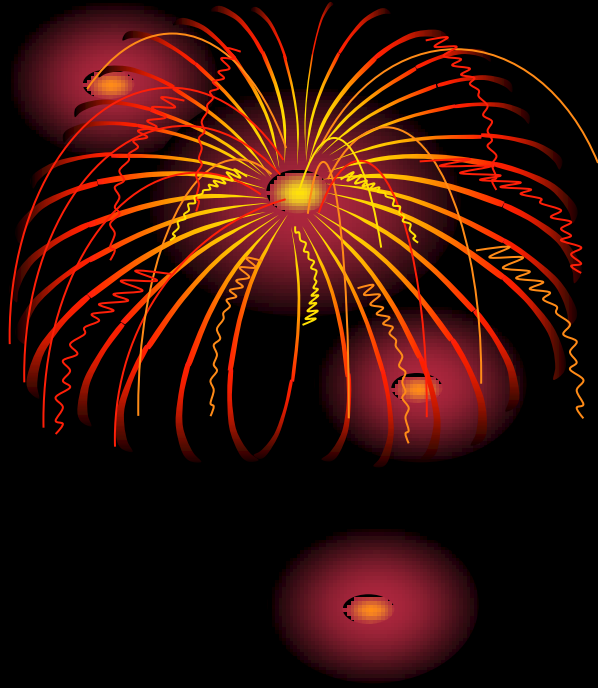
Millikan's Oil Drop Experiment





- Quarks: $q = \pm e/3 \text{ or } \pm 2e/3$

Charge is conserved



- The radioactive decay

$$^{238}U \rightarrow ^{234}Th + ^{4}He$$

- The annihilation process (對滅)

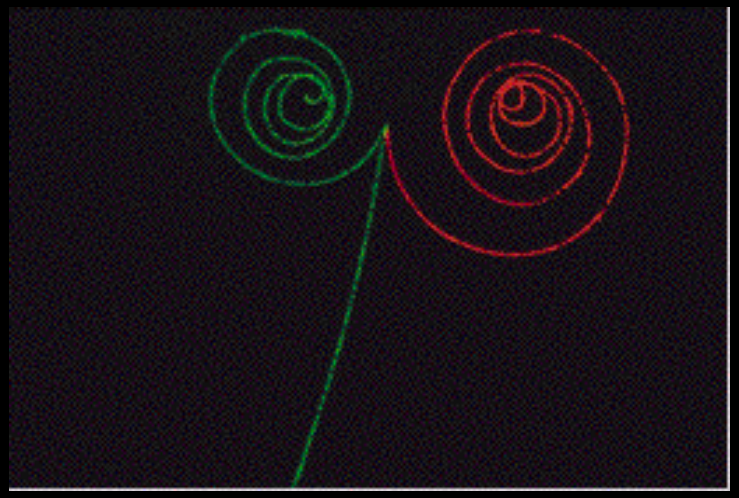
$$e^{-} + e^{+} \rightarrow \gamma + \gamma$$

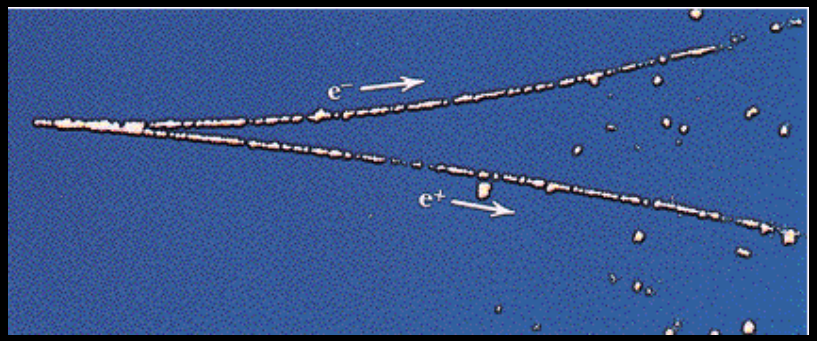
Elementary Particles

- The pair production process (對生)

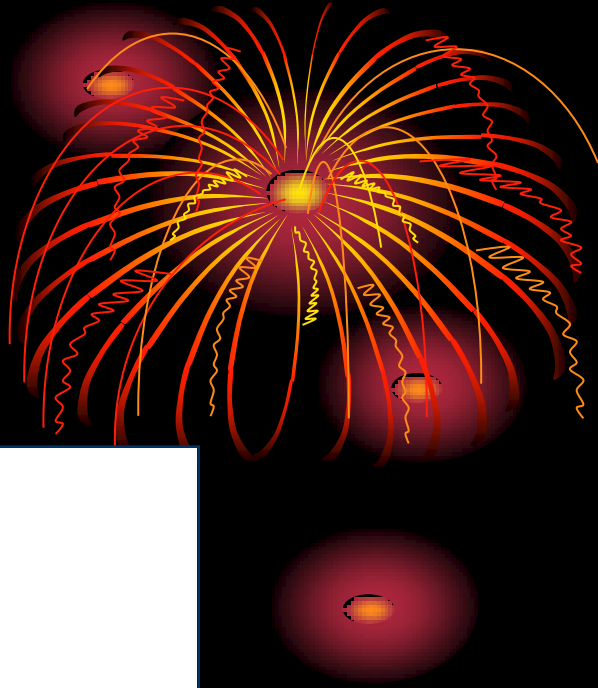
$$\gamma \rightarrow e^- + e^+$$

- The bubble (cloud) chamber





1.2 Coulomb's Law



$$F = k\frac{|q_1||q_2|}{r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99\times10^9\ N\cdot m^2/C^2$$

$$\varepsilon_0 = 8.85\times10^{-12} C^2/N\cdot m^2 = \text{permitivity}$$

Ex. 1-1 一庫倫負電荷含有多少電子

$$\mathrm{N}=\frac{\mathrm{q}}{\mathrm{e}}=\frac{1.00\mathrm{Coul}}{1.6\times10^{-19}\mathrm{C/e}}=6.25\times10^{18}e^{-}$$

Ex. 1-2 氫原子內電子與質子之間電力與重力之比

$$F_e=\frac{q_1q_2}{4\pi\varepsilon_0r^2}=\left(9\times10^9\,\frac{N\cdot m^2}{C^2}\right)\frac{\left(1.60\times10^{-19}C\right)^2}{\left(5.3\times10^{-11}m\right)^2}=8.2\times10^{-8}\,N$$

$$F_g=\frac{Gm_em_P}{r^2}=6.67\times10^{-11}\,\frac{Nm^2}{kg^2}\,\frac{\left(9.11\times10^{-31}kg\right)\left(1.67\times10^{-27}kg\right)}{\left(5.3\times10^{-11}m\right)^2}=3.6\times10^{-47}\,N$$

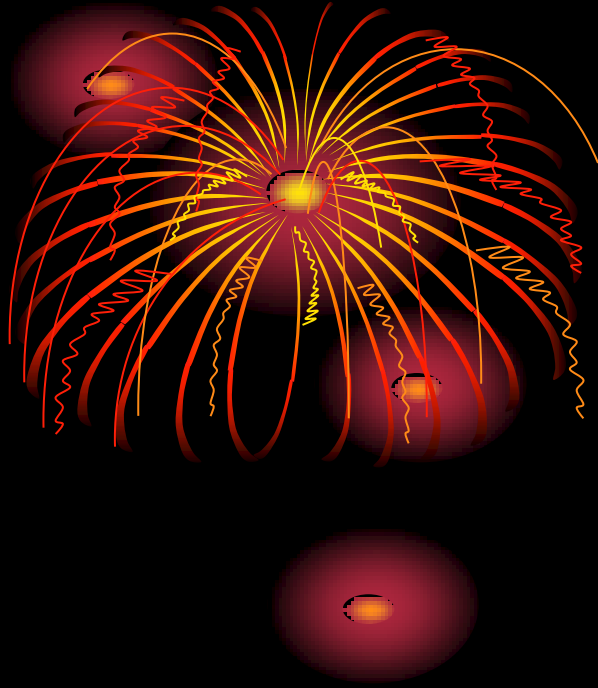
$$\frac{F_e}{F_g}=\frac{Kq_eq_P}{Gm_em_p}\cong10^{39}$$

Ex. 1-3 鐵（Fe^{26}）原子核中，兩個相距一個原子核半徑的質子間之斥力

$$F_e = \frac{q_P q_P}{4\pi\varepsilon_0 r^2} = 8.99\times10^9 \frac{N\cdot m^2}{C^2} \frac{\left(1.60\times10^{-19}C\right)^2}{\left(4\times10^{-15}m\right)^2} = 14N \sim 3lb$$

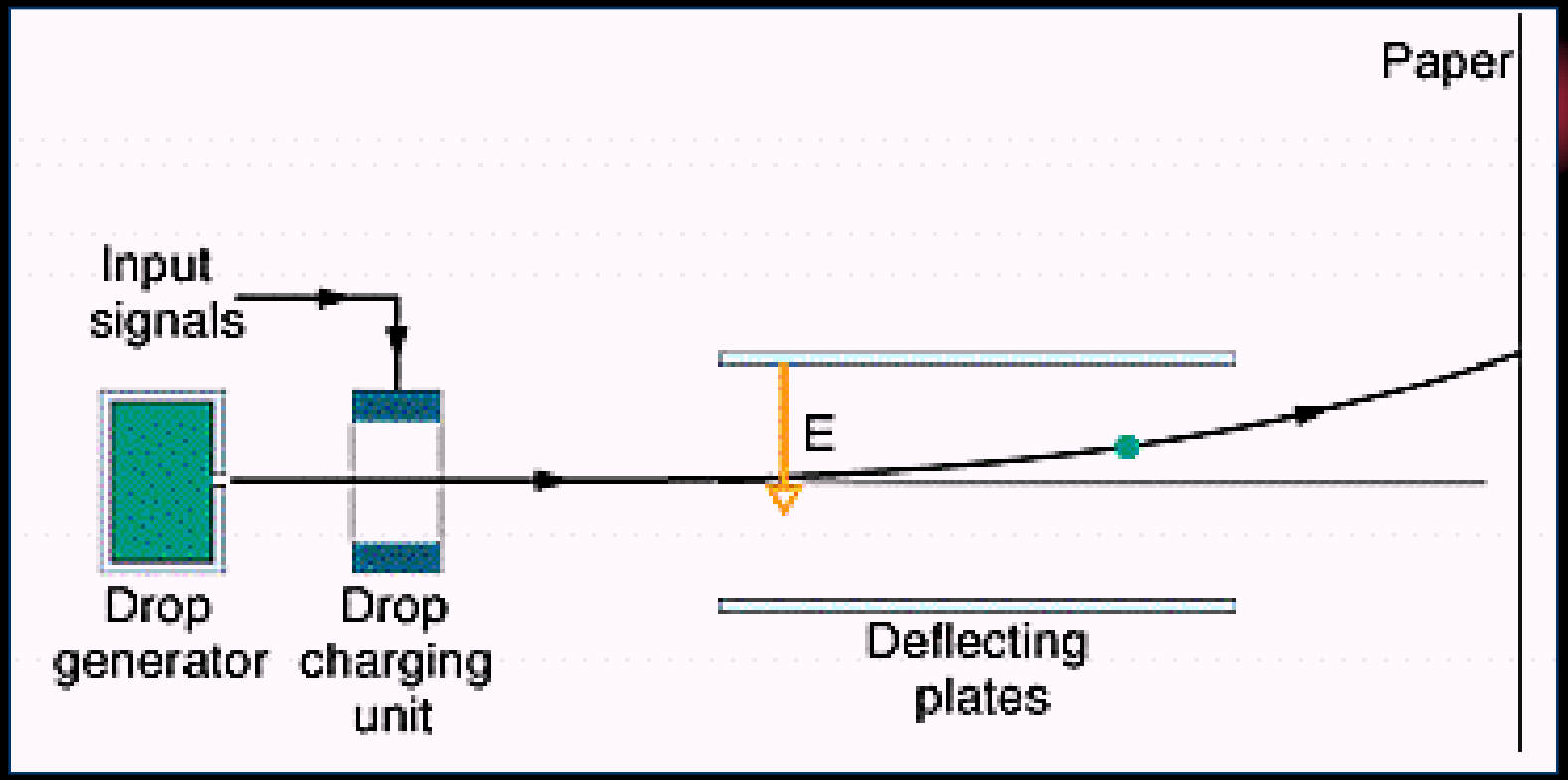
- $R = 4\times10^{-15}m$
- 如此大之斥力，必須有更強的核力與之抗衡，方能維持原子核的穩定。

1.3 靜電的應用



- Ink-Jet Printing
- Soil Decontamination
- Electroplating
- Electromagnetic Predators
- Electric Precipitator
- Xerography
- Laser Printer

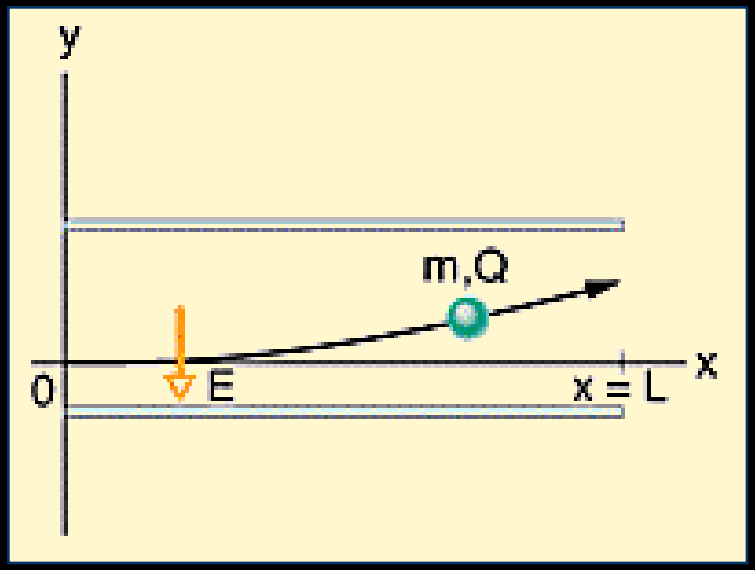
Ink-Jet Printing



An ink drop with

$m = 1.3 \times 10^{-10} kg$

$Q = 1.5 \times 10^{-13} C$



$L = 1.6\text{cm},\ v_x = 18\text{m/s}$

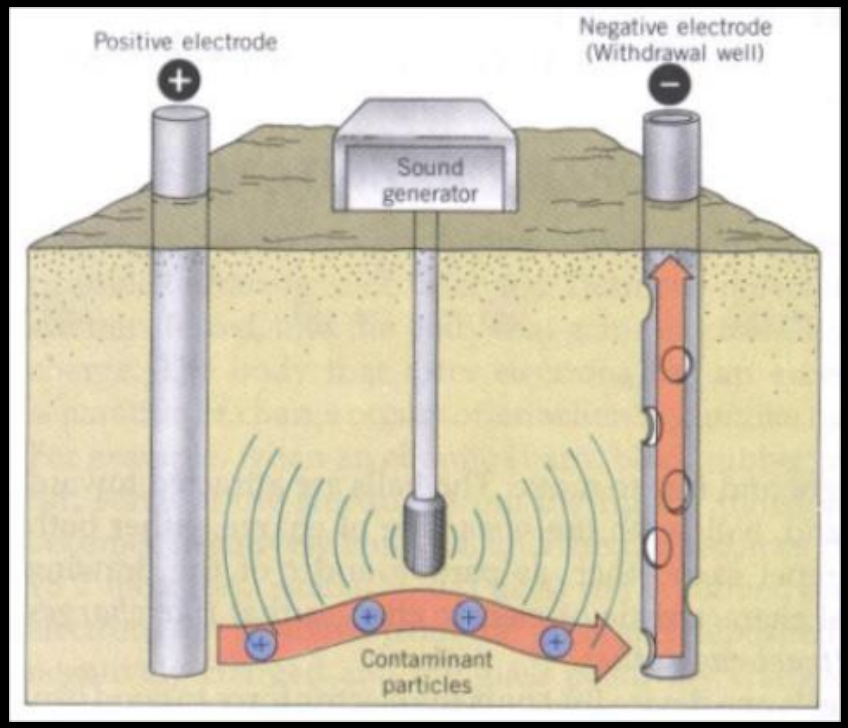
$E = 1.4 \times 10^6\ \text{N/C}$

$$a_y = \frac{F}{m} = \frac{QE}{m}$$

$$y = \frac{1}{2} a_y t^2,\ L = v_x t$$

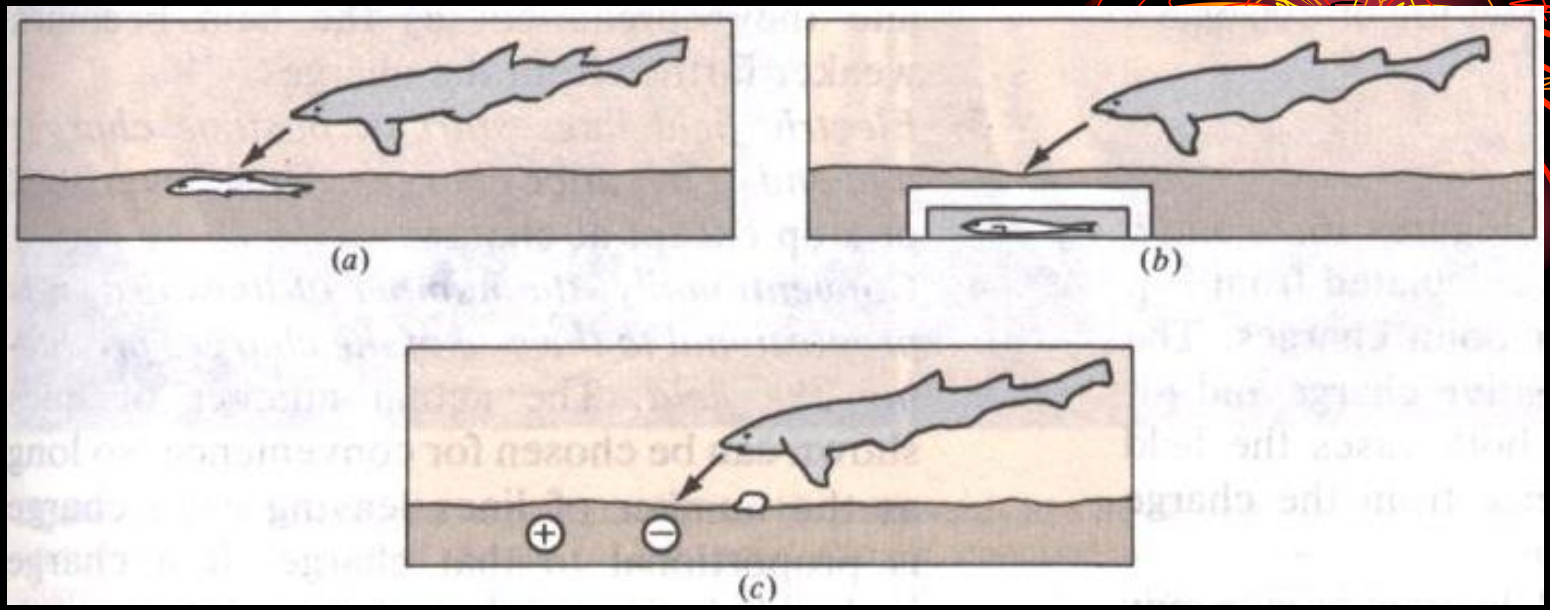
$$y = \frac{QEL^2}{2mv_x^2} = 0.64\text{mm}$$

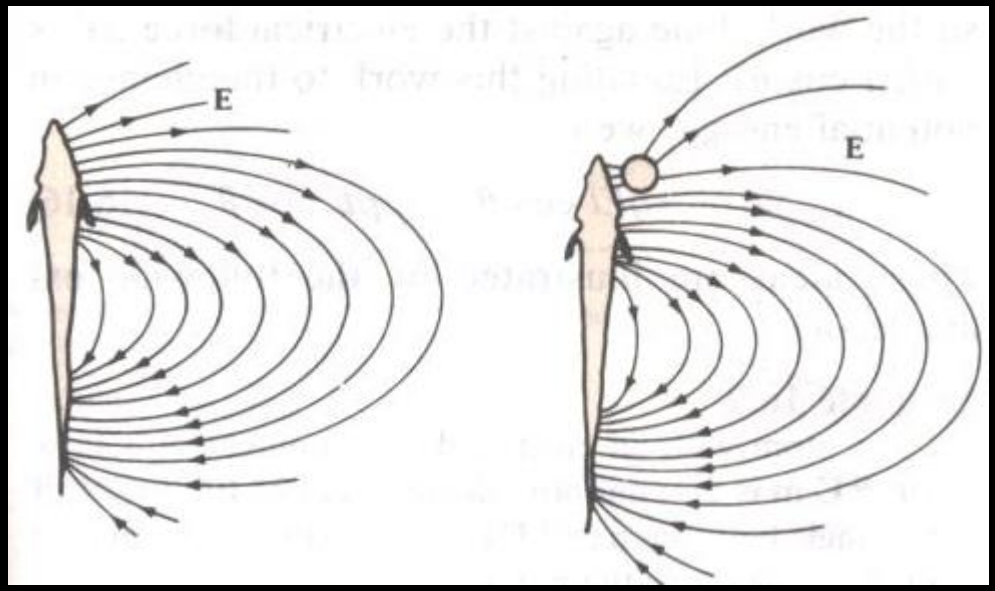
Soil Decontamination and Electroplating



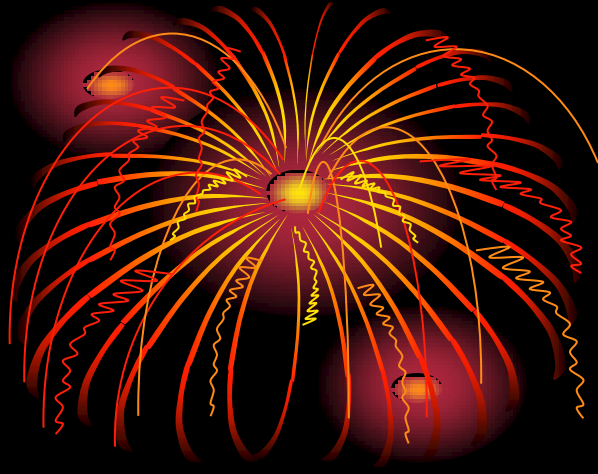
Electromagnetic Predators

電磁掠食者

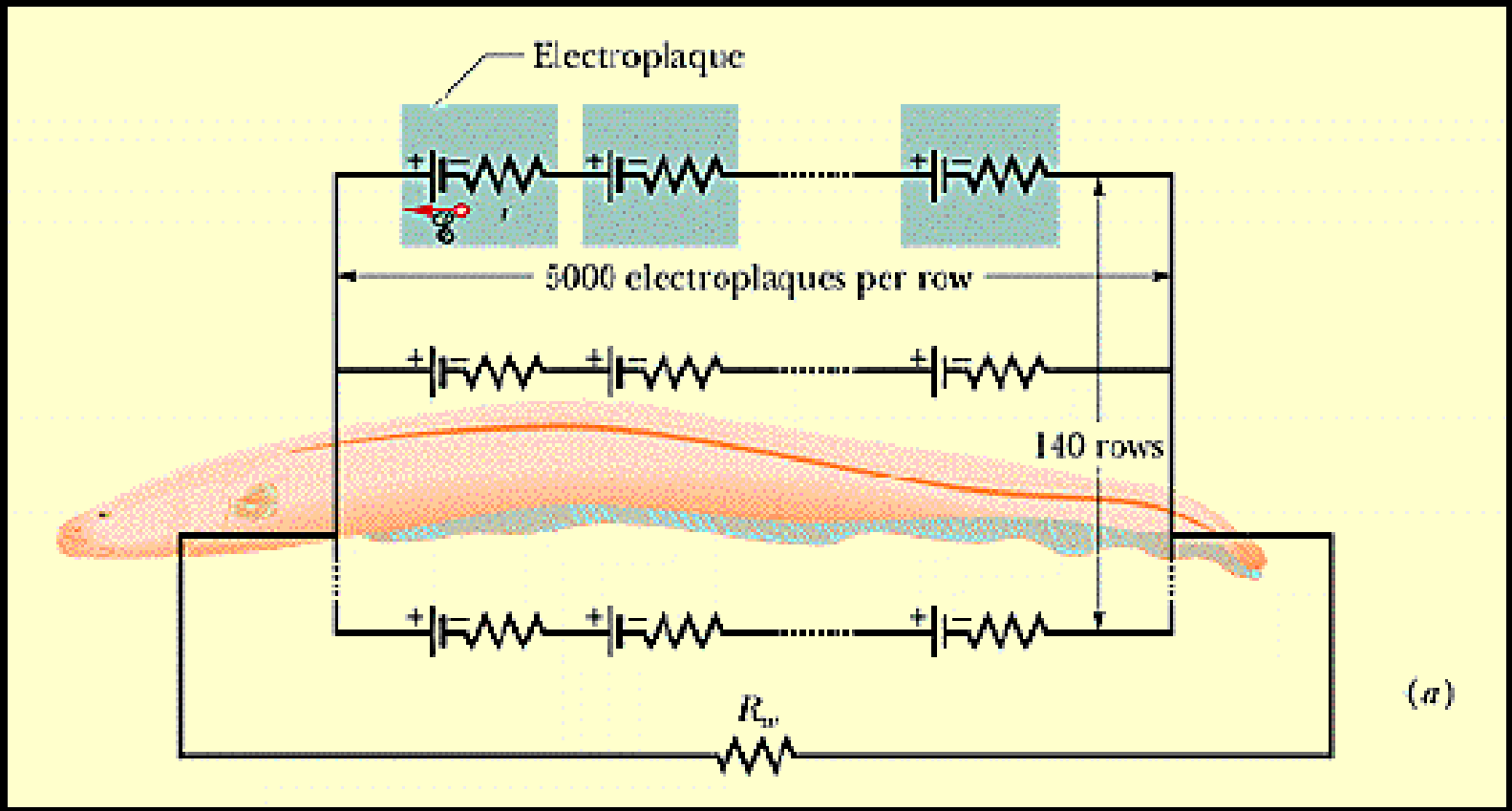




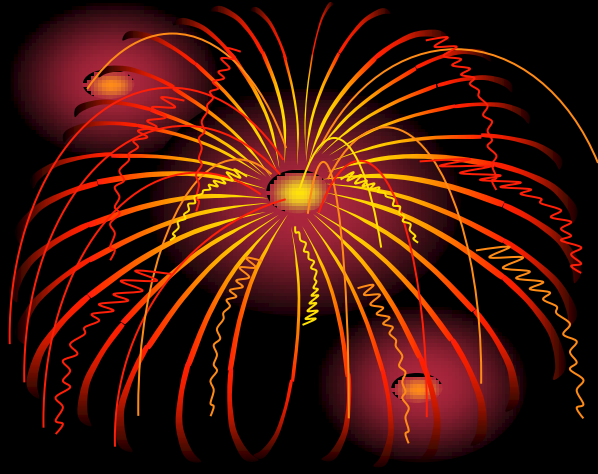
The torpedo ray and electric eel



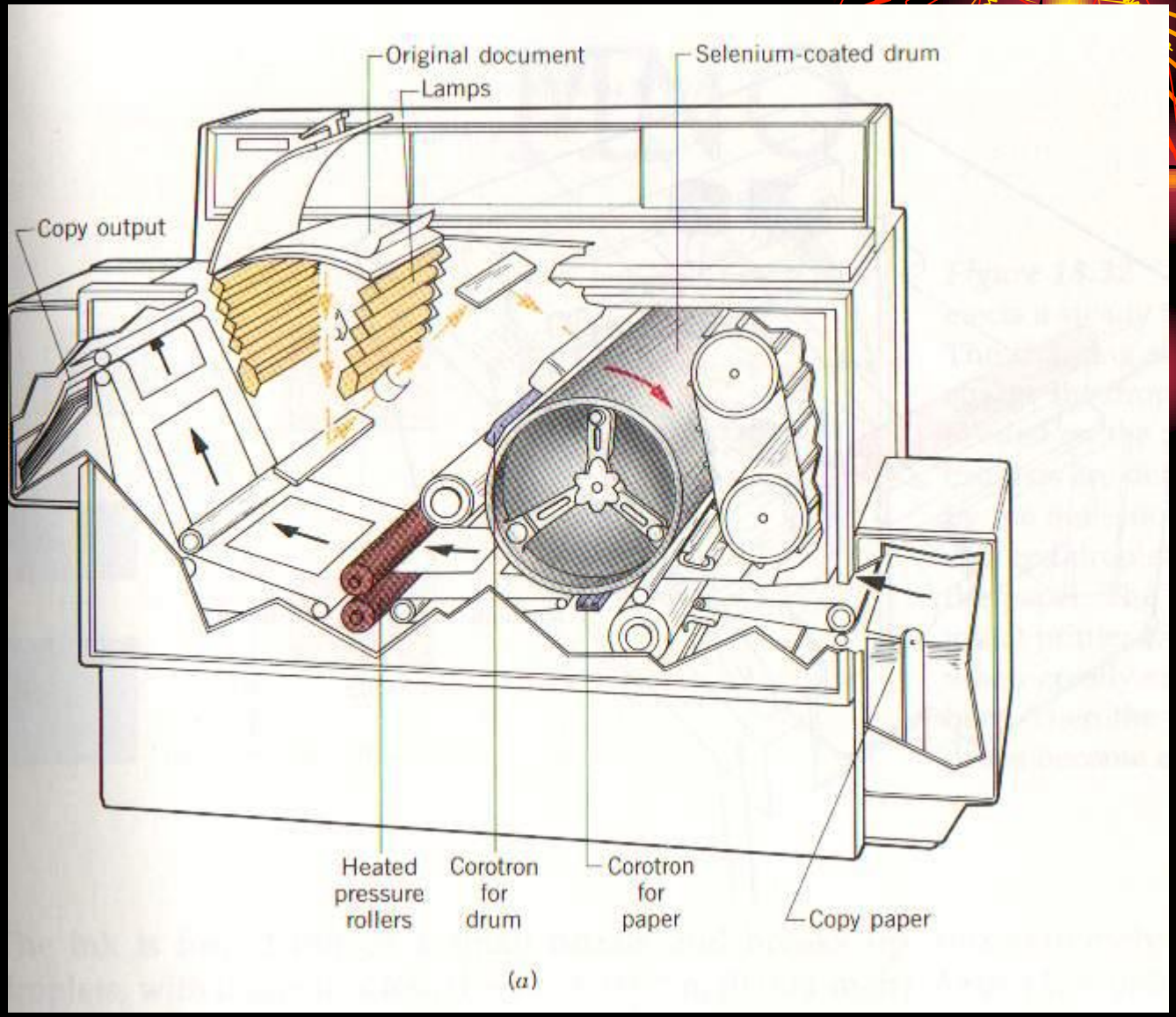
Electroplaques



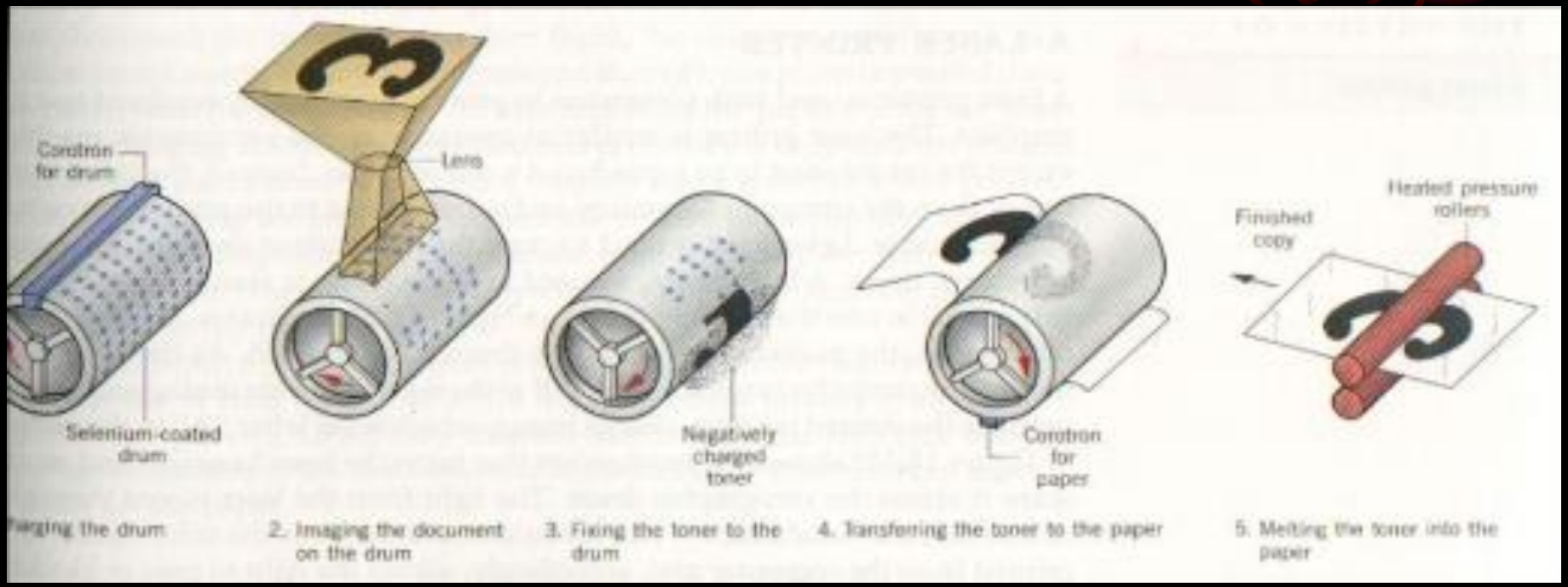
Electric Precipitator



影印機


Original document
Lamps
Selenium-coated drum
Copy output
Heated pressure rollers
Corotron for drum
Corotron for paper
Copy paper
(a)

The copying process



Laser Printer

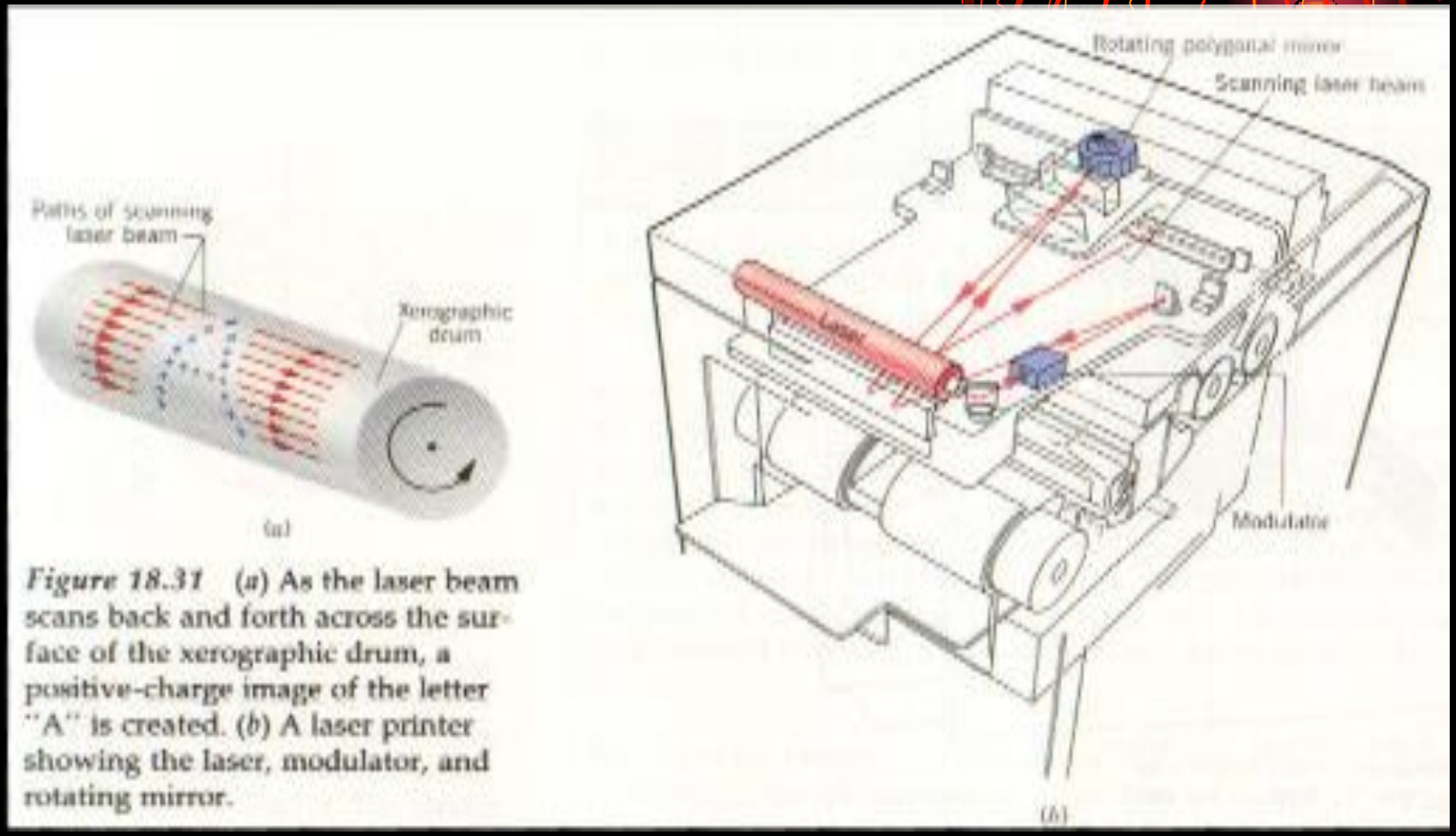
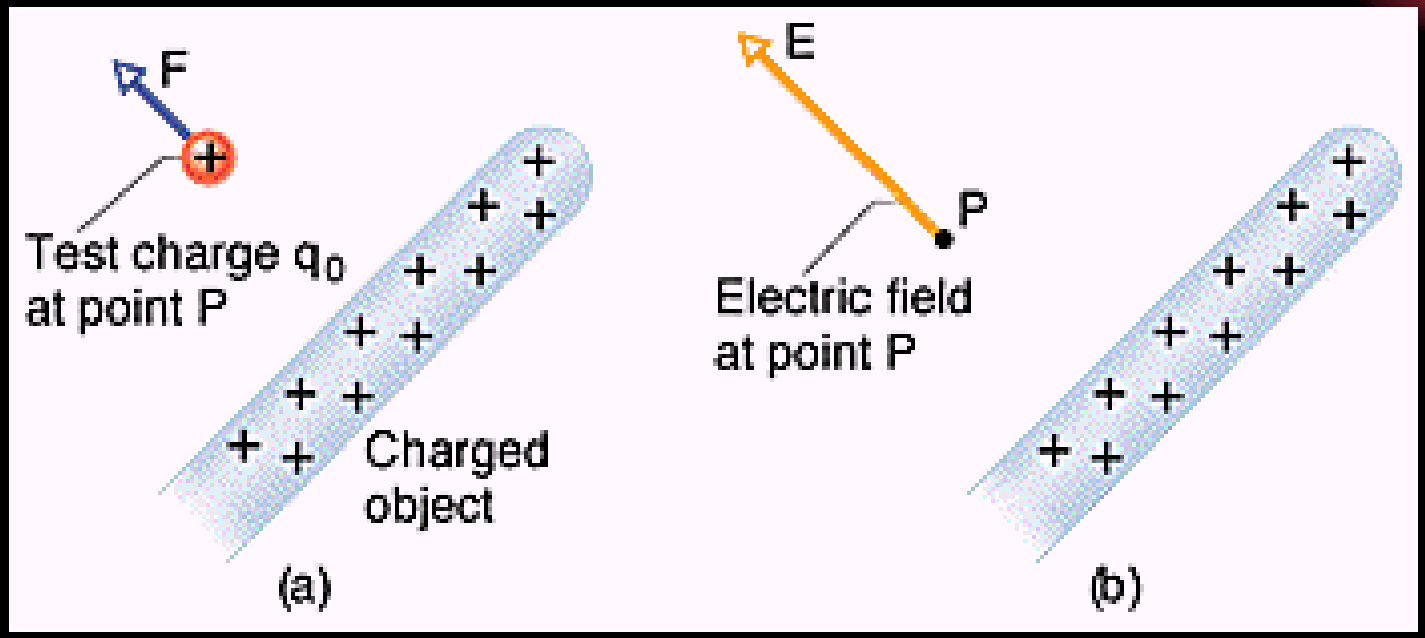


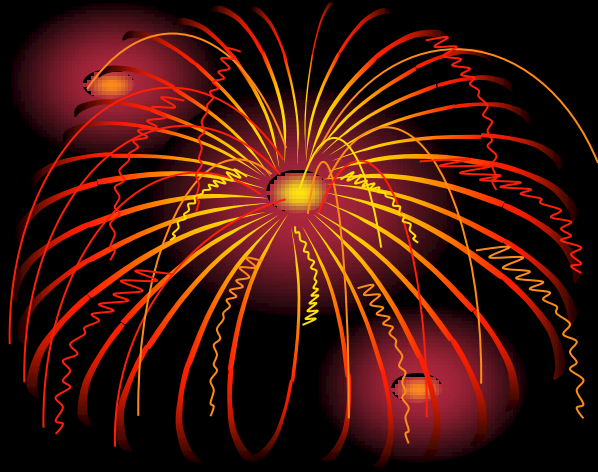
Figure 18.31 (*a*) As the laser beam scans back and forth across the surface of the xerographic drum, a positive-charge image of the letter "A" is created. (*b*) A laser printer showing the laser, modulator, and rotating mirror.

2 電場

- （electric field） （Lines of force）



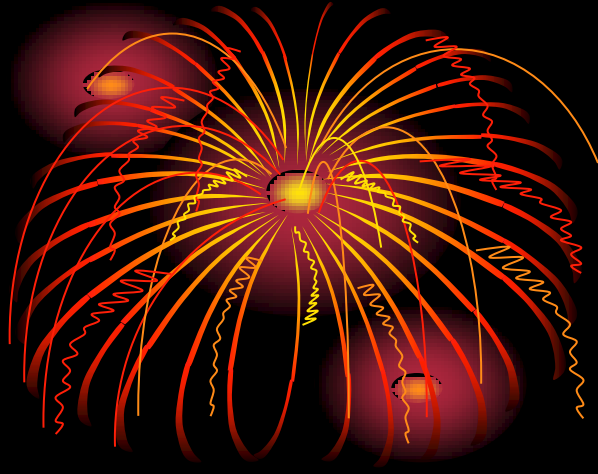
電場的定義

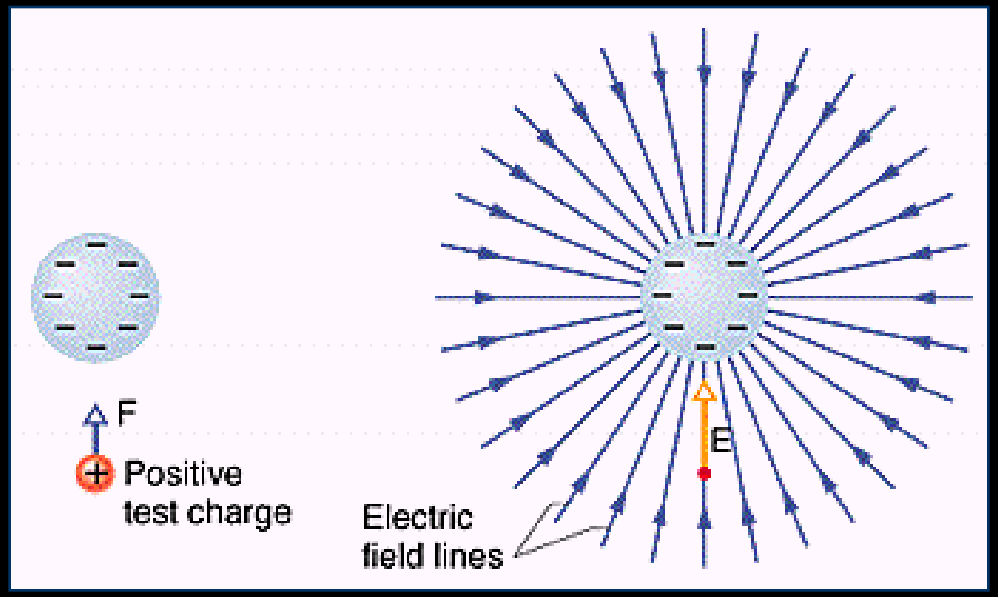


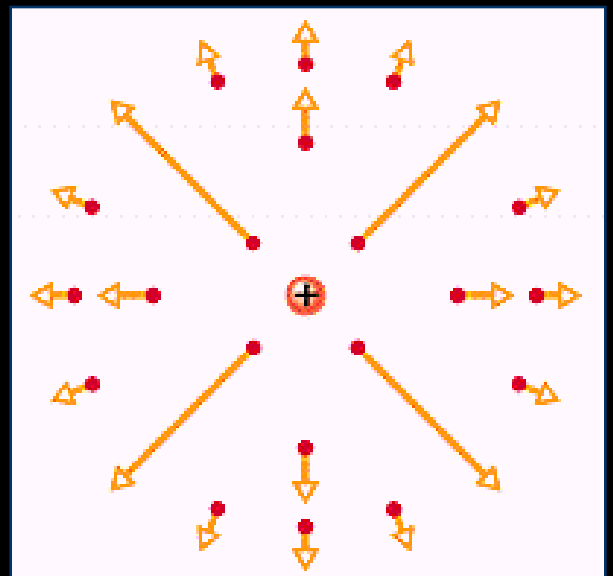
- 電力：q與q_0之間的電力 or
  q在q_0所建立的電場中受到的電力

$$\vec{E} = \frac{\vec{F}}{q_0} \ (\mathrm{N/C}) \ (\mathrm{V \cdot m})$$

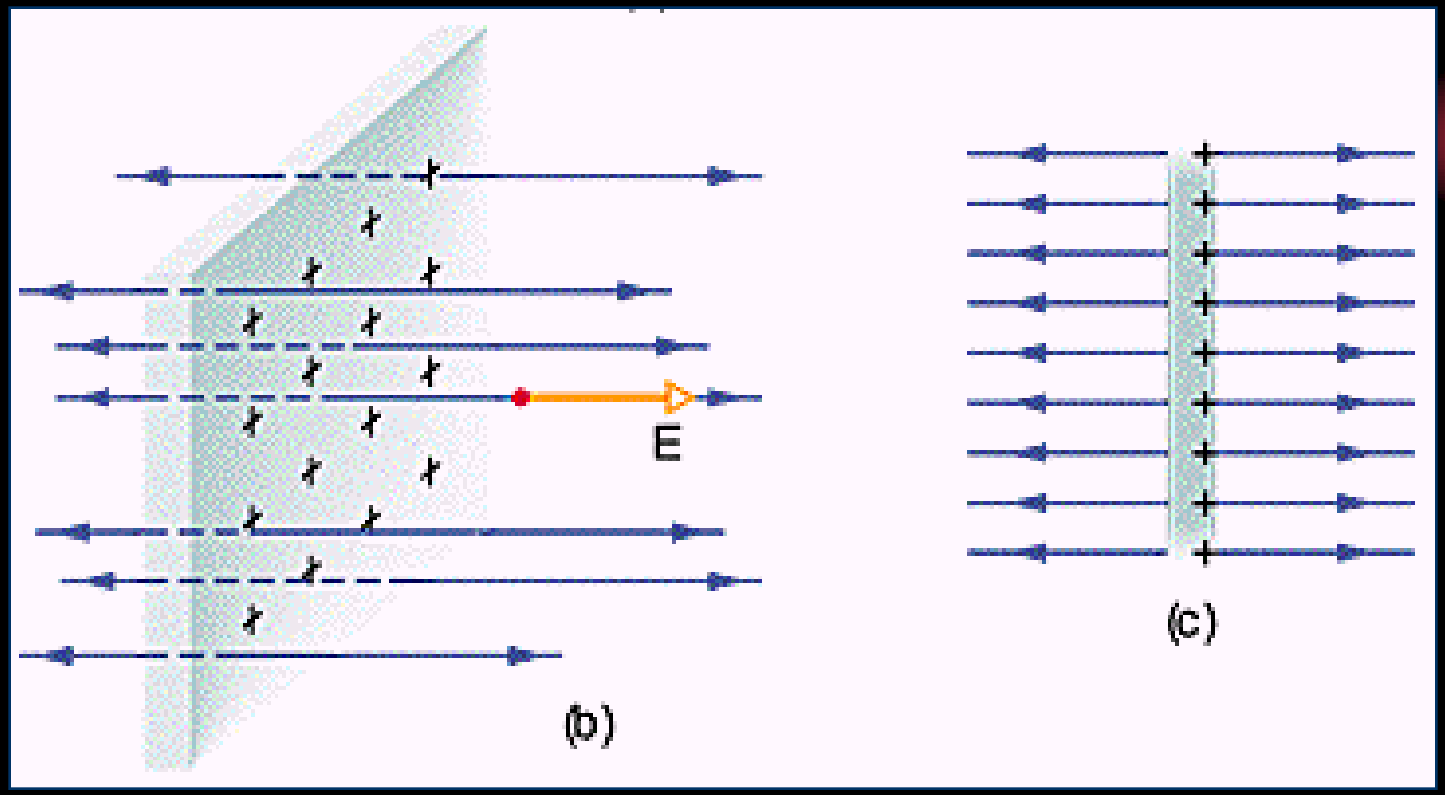
點電荷



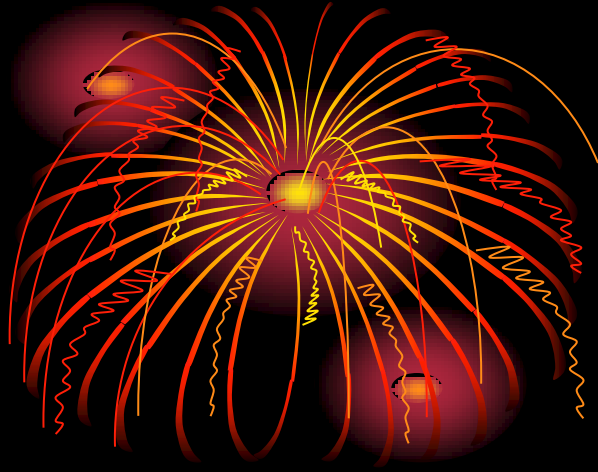




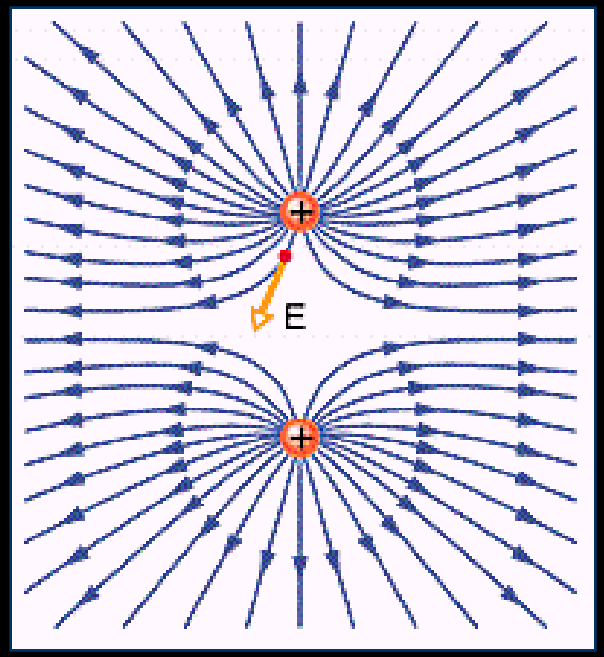
帶電平板

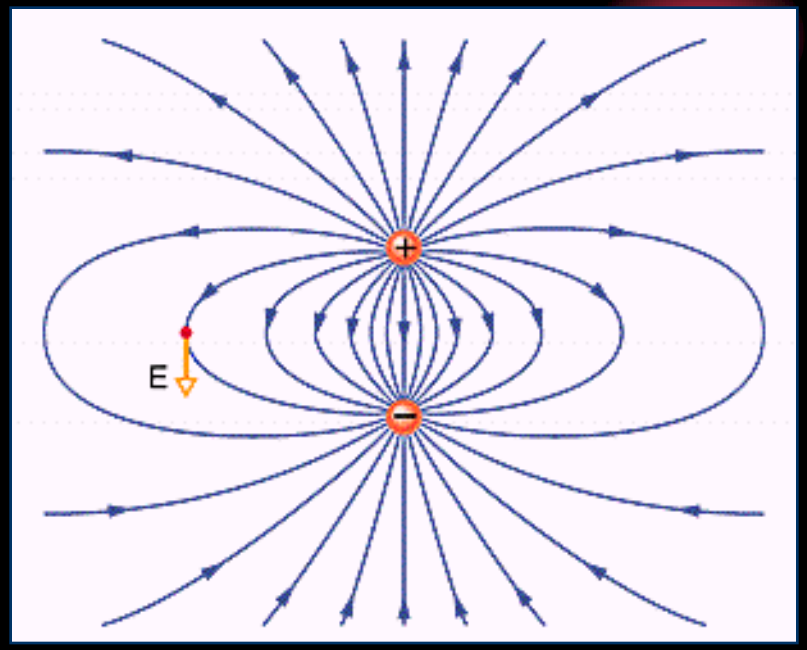


二正電荷與電雙極

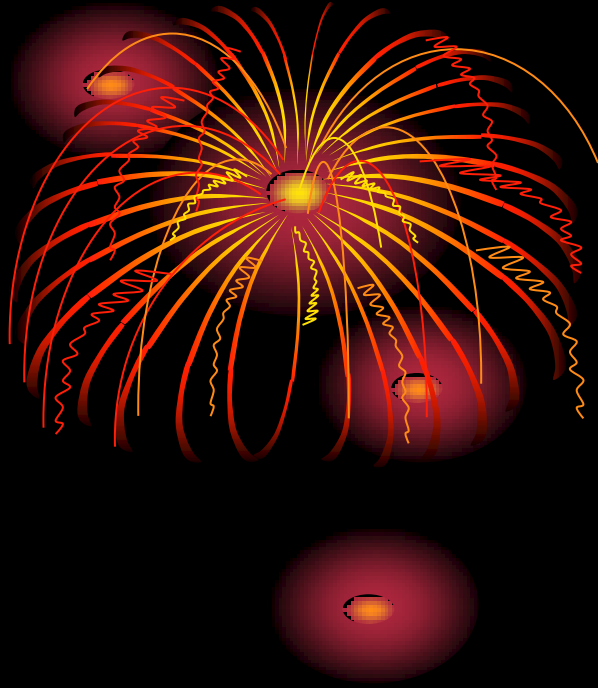


q_0



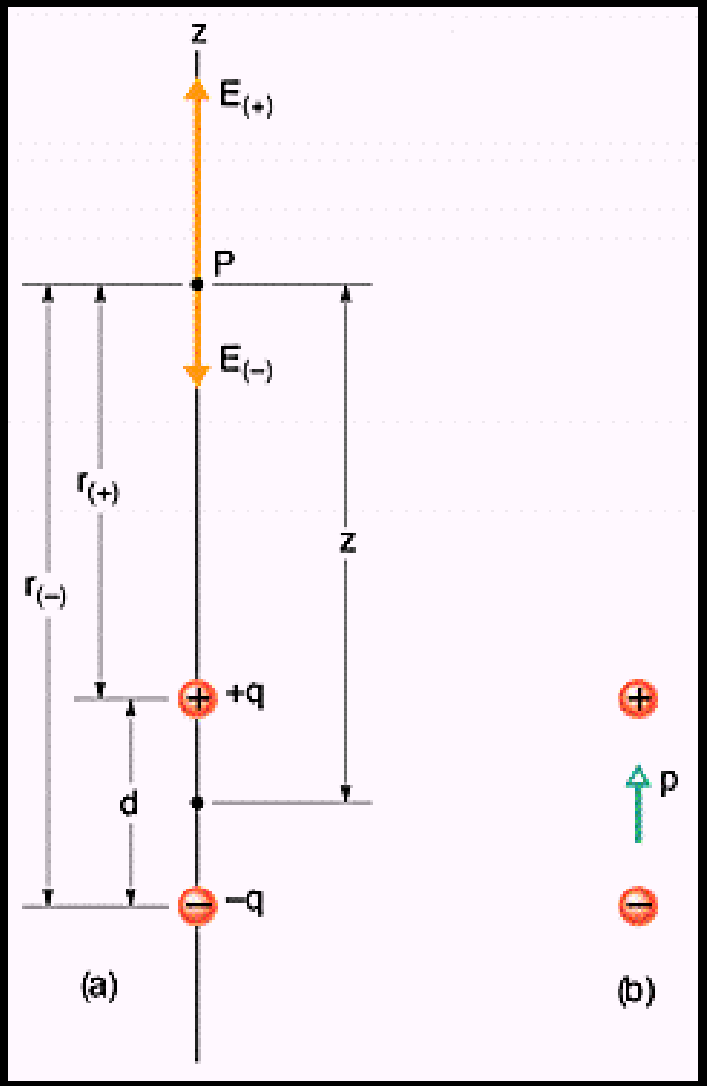


電場的計算



- 電雙極
- 均勻帶電圓環
- 均勻帶電圓盤

電雙極



兩電荷的電場相加

$$E = E_+ - E_-$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r_+^{\,2}} - \frac{1}{4\pi\varepsilon_0}\frac{q}{r_-^{\,2}}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(z-d/2)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(z+d/2)^2}$$

$$= \frac{q}{4\pi\varepsilon_0 z^2}\left[\left(1-\frac{d}{2z}\right)^{-2} - \left(1+\frac{d}{2z}\right)^{-2}\right]$$

電雙極的電場

$$= \frac{q}{4\pi\varepsilon_0 z^2}\left[\left(1+\frac{2d}{2z(1!)}+\ldots\right)-\left(1-\frac{2d}{2z(1!)}+\ldots\right)\right]$$

$$= \frac{q}{4\pi\varepsilon_0 z^2}\left[\left(1+\frac{d}{z}+\ldots\right)-\left(1-\frac{d}{z}+\ldots\right)\right]$$

$$= \frac{q}{4\pi\varepsilon_0 z^2}\frac{2d}{z} = \frac{1}{2\pi\varepsilon_0}\frac{qd}{z^3}$$

$$E = \frac{1}{2\pi\varepsilon_0}\frac{p}{z^3} \quad \text{(electric dipole)}$$

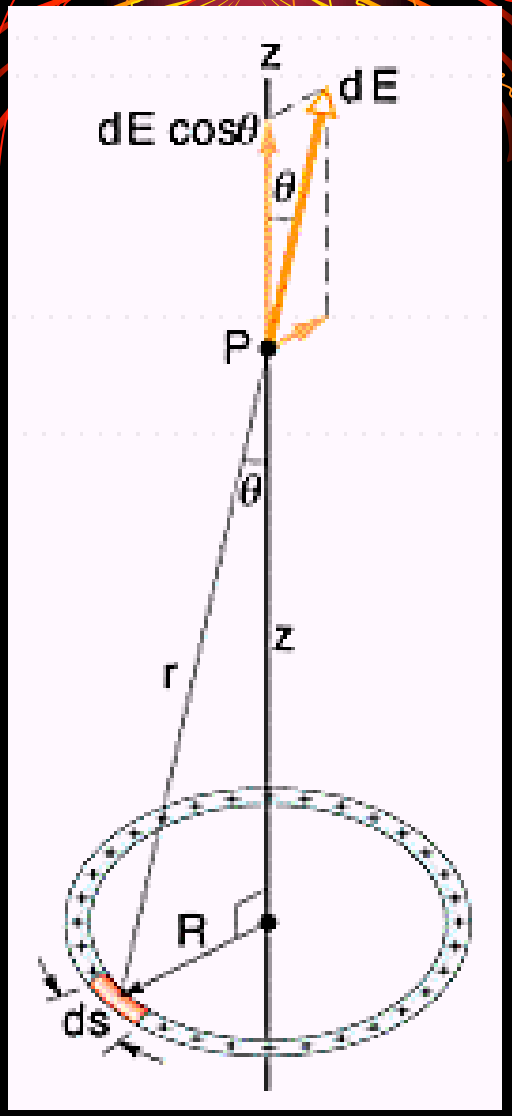
$\vec{p}$ = elcectric dipole moment (電雙極矩)

均勻帶電圓環

$$dq = \lambda ds$$

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda ds}{r^2}$$

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{\lambda ds}{(z^2 + R^2)}$$



均勻帶電圓環的電場

$$dE \rightarrow dE\cos\theta,\ \cos\theta = \frac{z}{r} = \frac{z}{(z^2+R^2)^{1/2}}$$

$$dE\cos\theta = \frac{z\lambda}{4\pi\varepsilon_0(z^2+R^2)^{3/2}}ds$$

$$E = \int dE\cos\theta = \frac{z\lambda}{4\pi\varepsilon_0(z^2+R^2)^{3/2}}\int_0^{2\pi R} ds$$

$$= \frac{z\lambda(2\pi R)}{4\pi\varepsilon_0(z^2+R^2)^{3/2}} = \frac{qz}{4\pi\varepsilon_0(z^2+R^2)^{3/2}}$$

極限情形

- If z » R, $z^2 + R^2 \rightarrow z^2$

$$E = \frac{qz}{4\pi\varepsilon_0 (z^2 + R^2)^{3/2}}$$

$$\rightarrow \frac{1}{4\pi\varepsilon_0}\frac{q}{z^2} \text{ (like a point charge)}$$

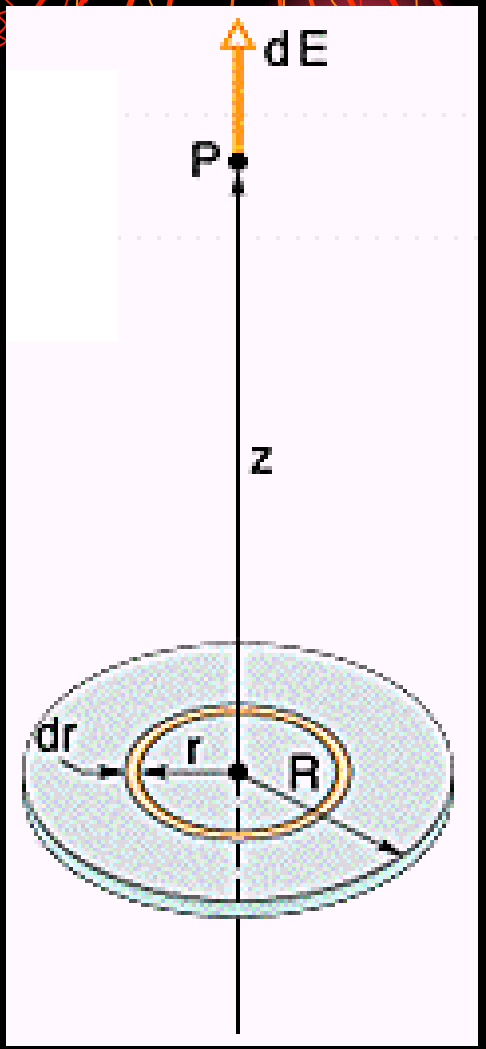
均勻帶電圓盤

$$dq = \sigma dA = \sigma 2\pi r dr$$

$$dE = \frac{z\sigma 2\pi r dr}{4\pi\varepsilon_0 (z^2 + r^2)^{3/2}}$$

$$dE = \frac{\sigma z}{4\varepsilon_0} \frac{2r dr}{(z^2 + r^2)^{3/2}}$$

$$E = \int dE = \frac{\sigma z}{4\varepsilon_0} \int_0^R (z^2 + r^2)^{-3/2} (2r) dr$$



均勻帶電圓盤的電場

$$E = \int dE = \frac{\sigma z}{4\varepsilon_0}\int_0^R (z^2 + r^2)^{-3/2}(2r)dr$$

$$= \frac{\sigma z}{4\varepsilon_0}\left[\frac{(z^2 + r^2)^{-1/2}}{-1/2}\right]_0^R$$

$$= \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{z}{\sqrt{z^2 + R^2}}\right) \to \frac{\sigma}{2\varepsilon_0}$$

The electric field on an oil drop

A drop of R = 2.76μm has 3 excess electrons, ρ = 920kg/m^3

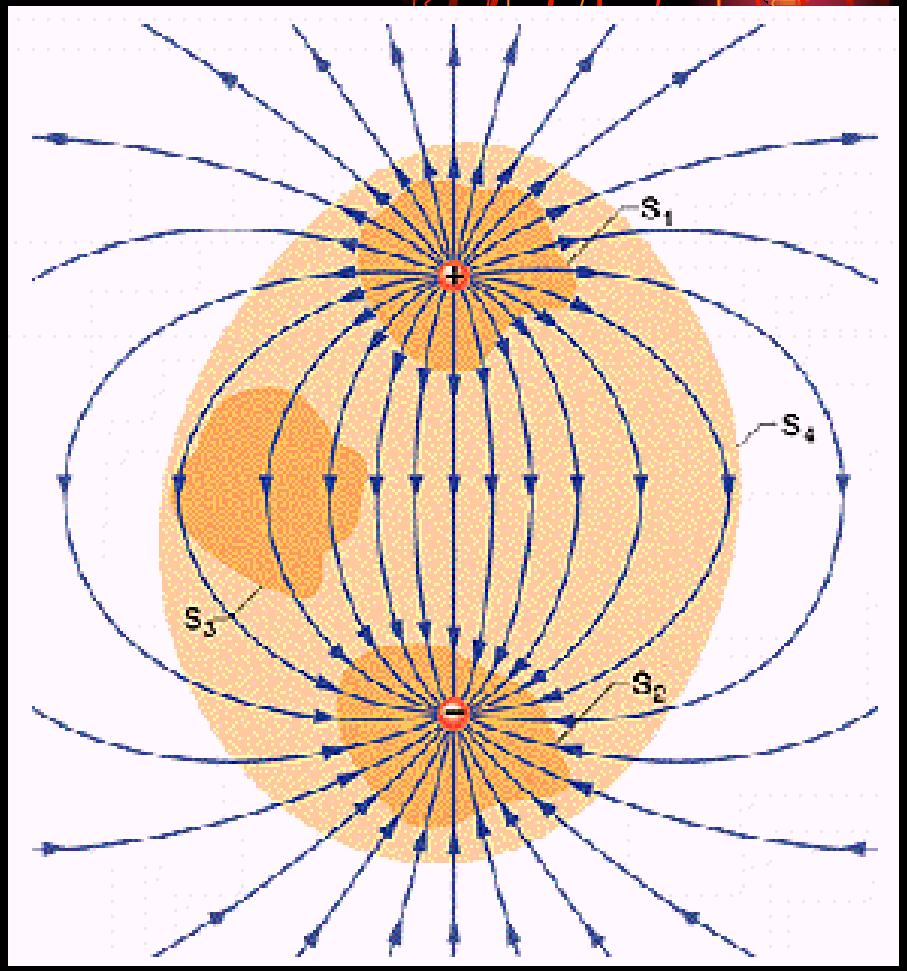
$$F_g = \frac{4}{3}\pi R^3 \rho g = (3e)E = F_e$$

$$E = \frac{4\pi R^3 \rho g}{9e} = 1.65\times 10^6\, N/C$$

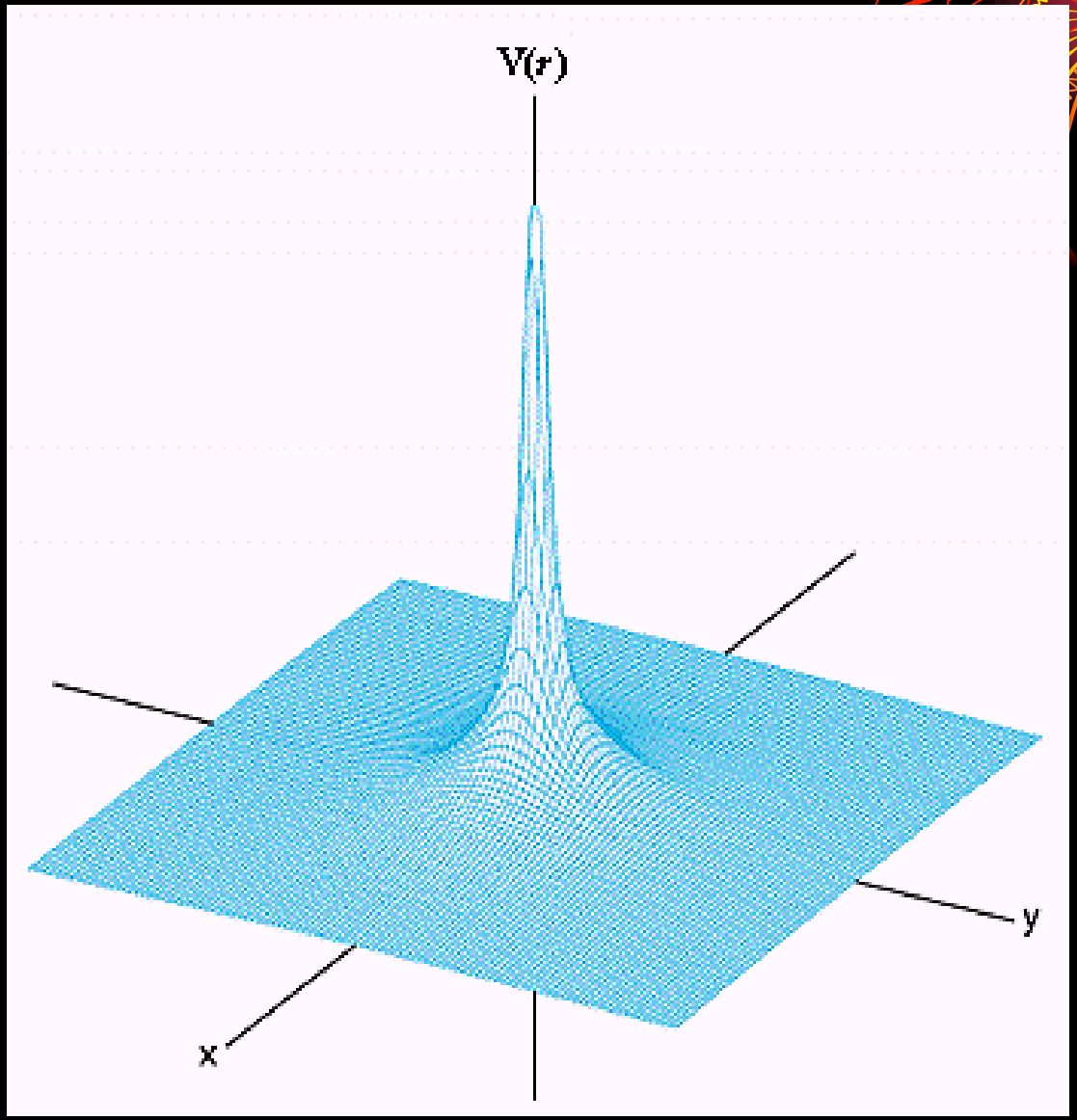
3 高斯定律 Gauss' Law

- Flux ↔ enclosed charge

$$\varepsilon_0 \Phi = \varepsilon_0 \oint \vec{E} \cdot d\vec{A} = q_{enc}$$

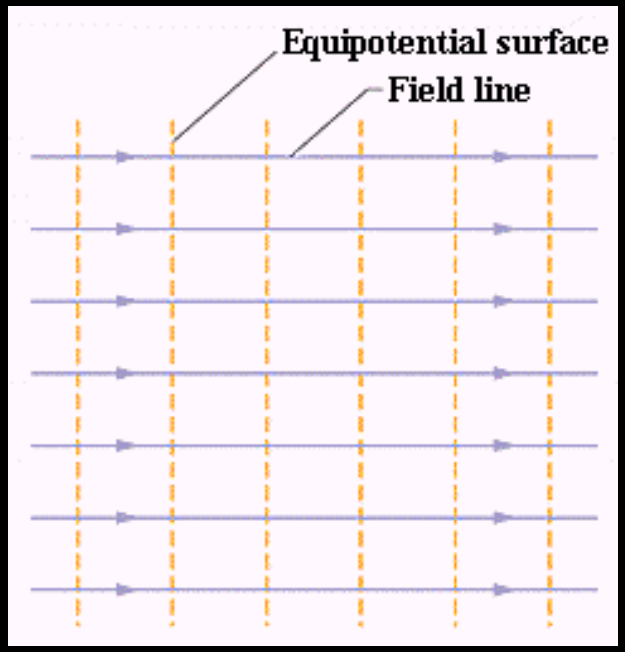


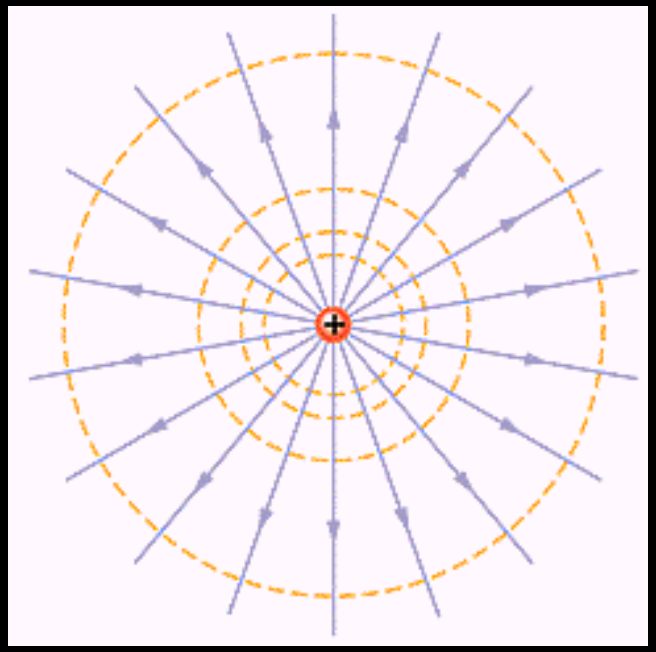
點電荷的電位圖

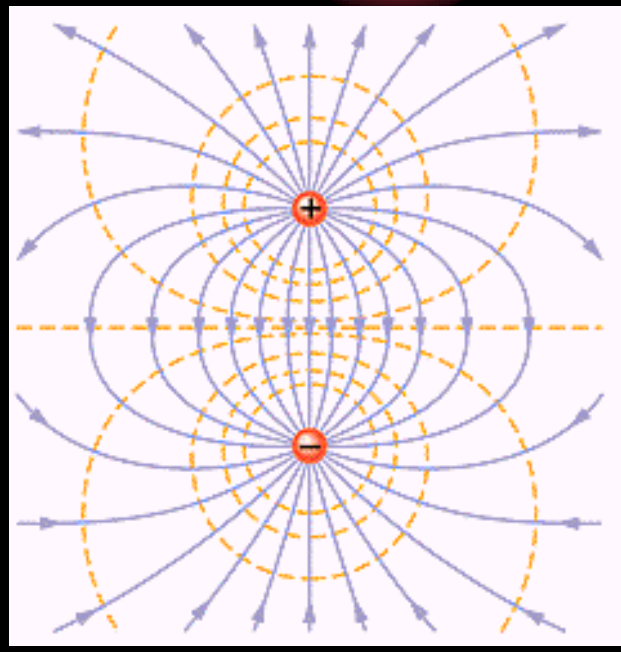


等位面3例

- E.S. for a uniform field, a point charge, and an electric dipole



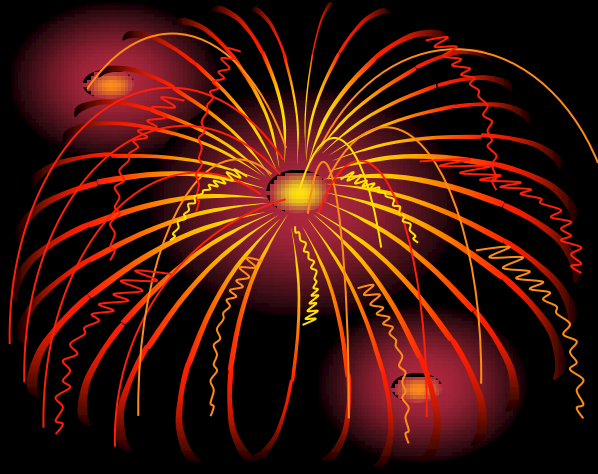


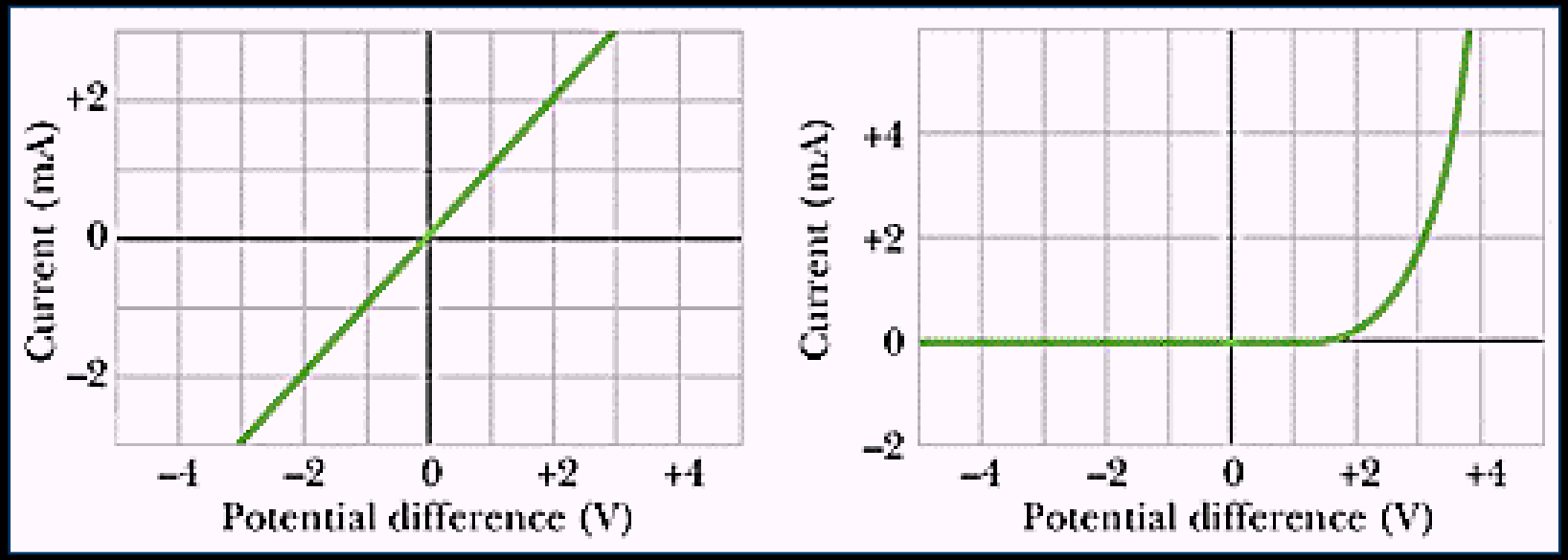


電容器


SIEMENS
SPRAGUE
POWERLYTIC®
36DE
81000-400C
8726L 2201
MADE IN USA
+95°C
ELNA
CE-W
75V 8000μF
BLACK-NEG

6 I-V curves

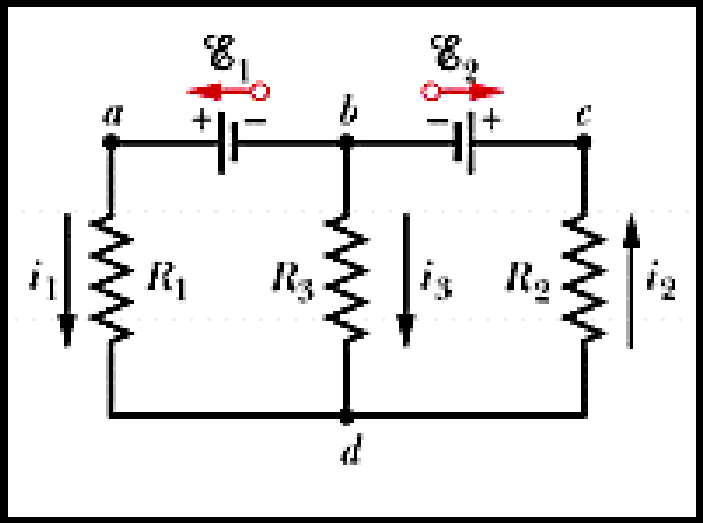




conductor

semiconductor

7 Multiloop Circuits



$$i_1 + i_3 = i_2$$

- The Junction rule: 流入接點之電流必等於流出者
  (Kirchhoff's junction/current rule)

8 電流與磁場

- The electric field and the magnetic field
- Electromagnets and permanent magnets

9 電磁感應

How did the electric guitar revolutionize rock?

From acoustic to electric guitars

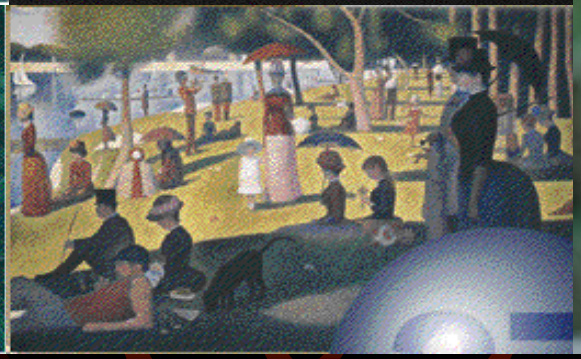
10 Magnetism of Matter

How can a clay-walled kiln reveal Earth's magnetic field of the past?

11 反射、折射、干涉、繞射







12 量子物理