普通的物理 和
非凡的永續能源採汲術

粘正勳

物理系
表面物理實驗室

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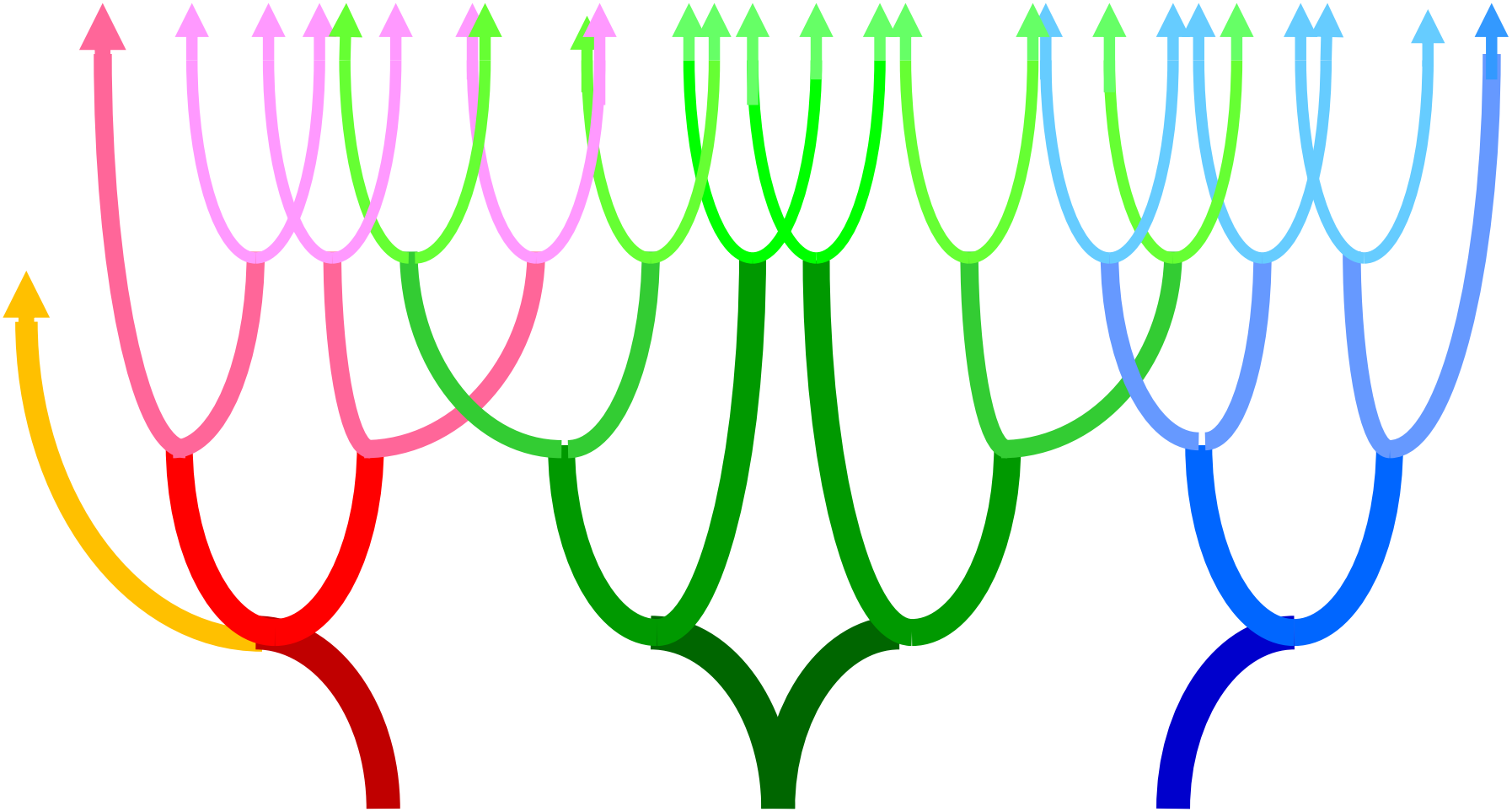
理學院教學館101教室
109年 10月 27日 (星期二)

表面物理實驗室

＊ 主流(傳統)的表面物理：研究固體表面或介面的物理現象及其應用。

＊ 非典型(另類)的表面物理：善用表面或介面的物理知識，以開發新穎的科技領域。



另類綠能科技的研發

(1) 新型的(超級)電容器 ➔ 有效的電能儲存裝置

(2) 非電磁感應式的發電機制 ➔ 有效汲取各種再生能源

(3) 箔式(非典型)的平價光電池 ➔ 普及太陽能的接收利用

(4) 表面張力仲介的光能汲取裝置 ➔ 開發新型的太陽能利用

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Parallel-Plate Capacitor

small plate separation ➔ ignored fringing fields (fringe effects) at the ends

assume : uniform field ⇨ $V = E\,d$

$E = \sigma/\varepsilon_0 = Q/\varepsilon_0 A$ (surface charge density : $\sigma = Q/A$)

$C \equiv Q/V = \varepsilon_0 A/d$ permittivity : $\varepsilon_0 =$ 8.85 x 10^{-12} (F/m)

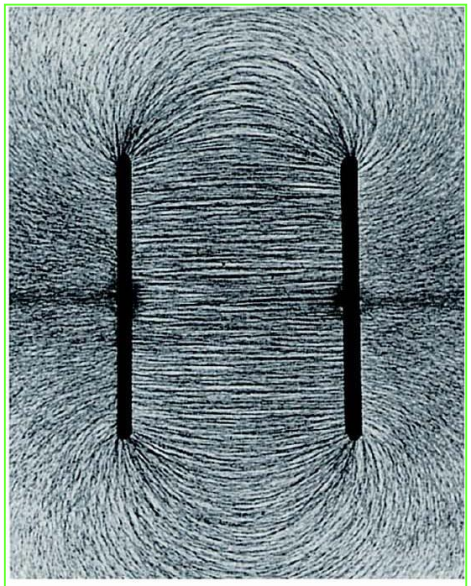


圖 26.3
兩塊電性相反且大小有限之平板，所造成的電場並不均勻。

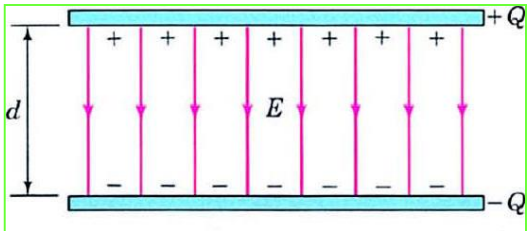


圖 26.4
當平板間距極小時，邊緣效應可被忽略，電場仍可被視為均勻的。

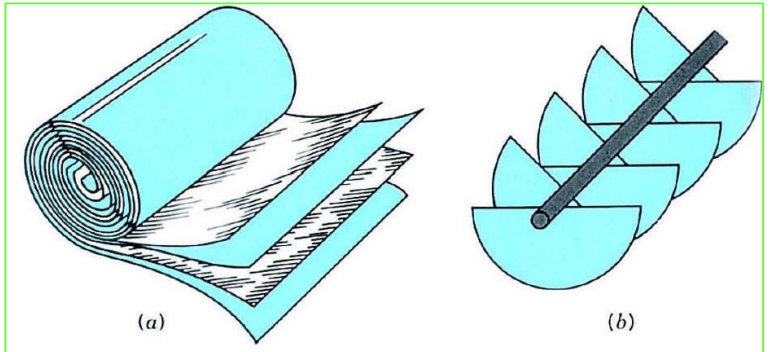
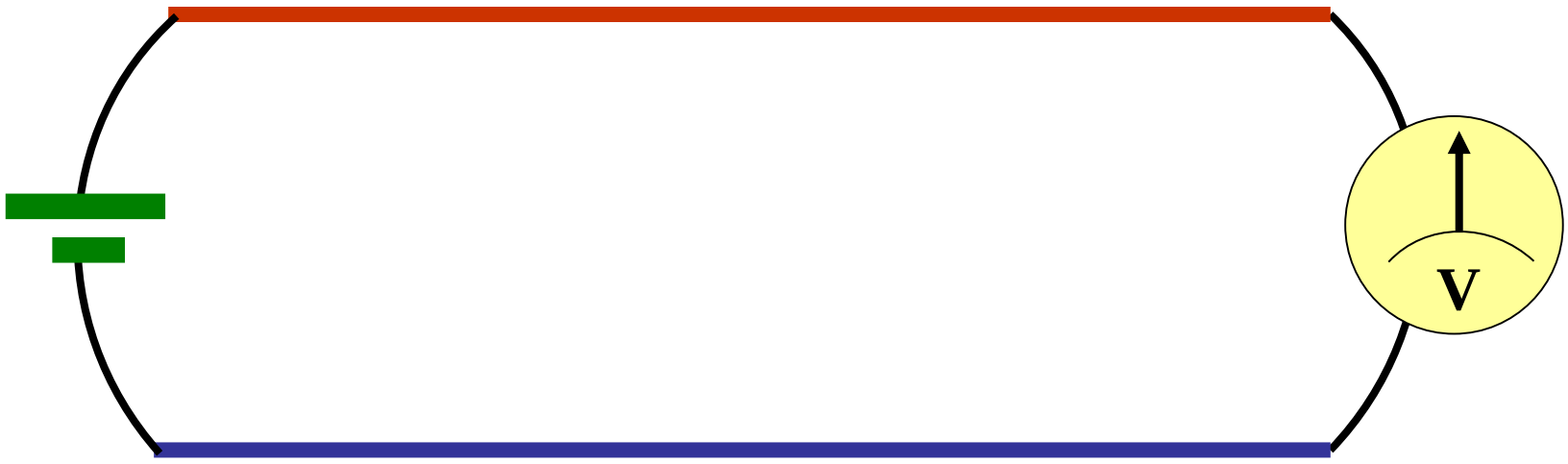


圖 26.5
(a) 將塑膠物質包入金屬箔片中而製成電容。
(b) 可變電容。電容大小視兩組板子間之重疊部份而定；一組板子固定，另一組可轉動。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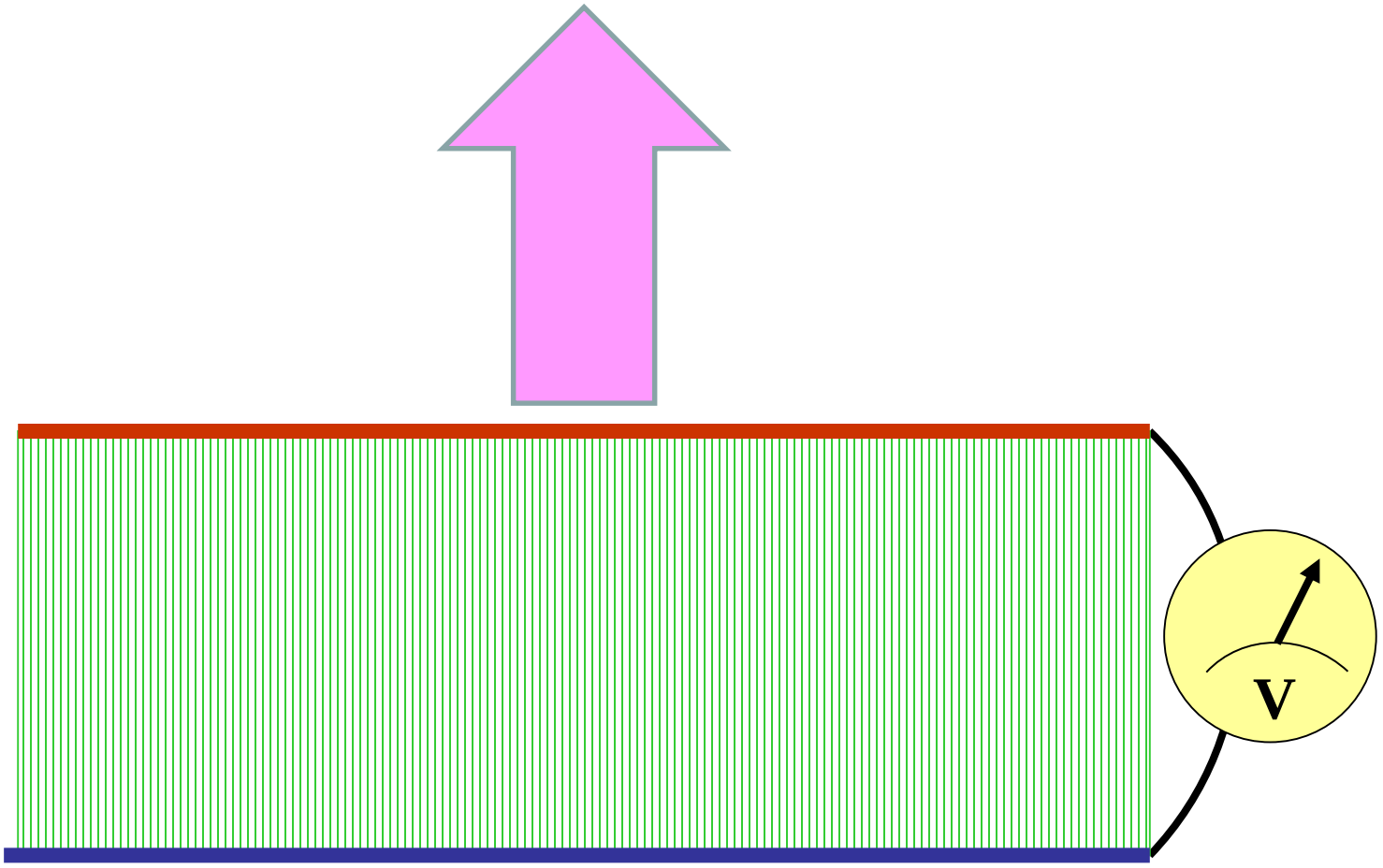
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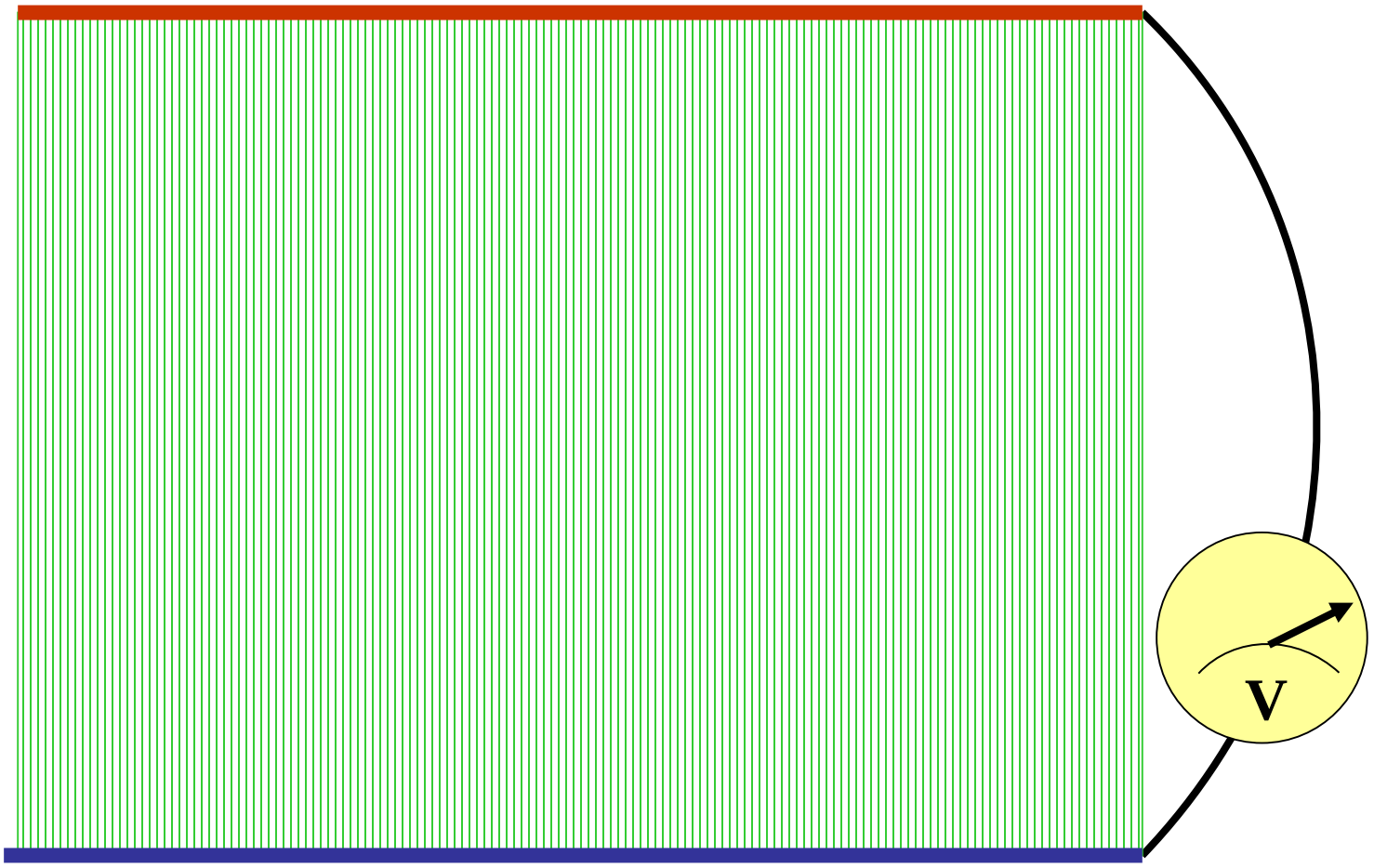
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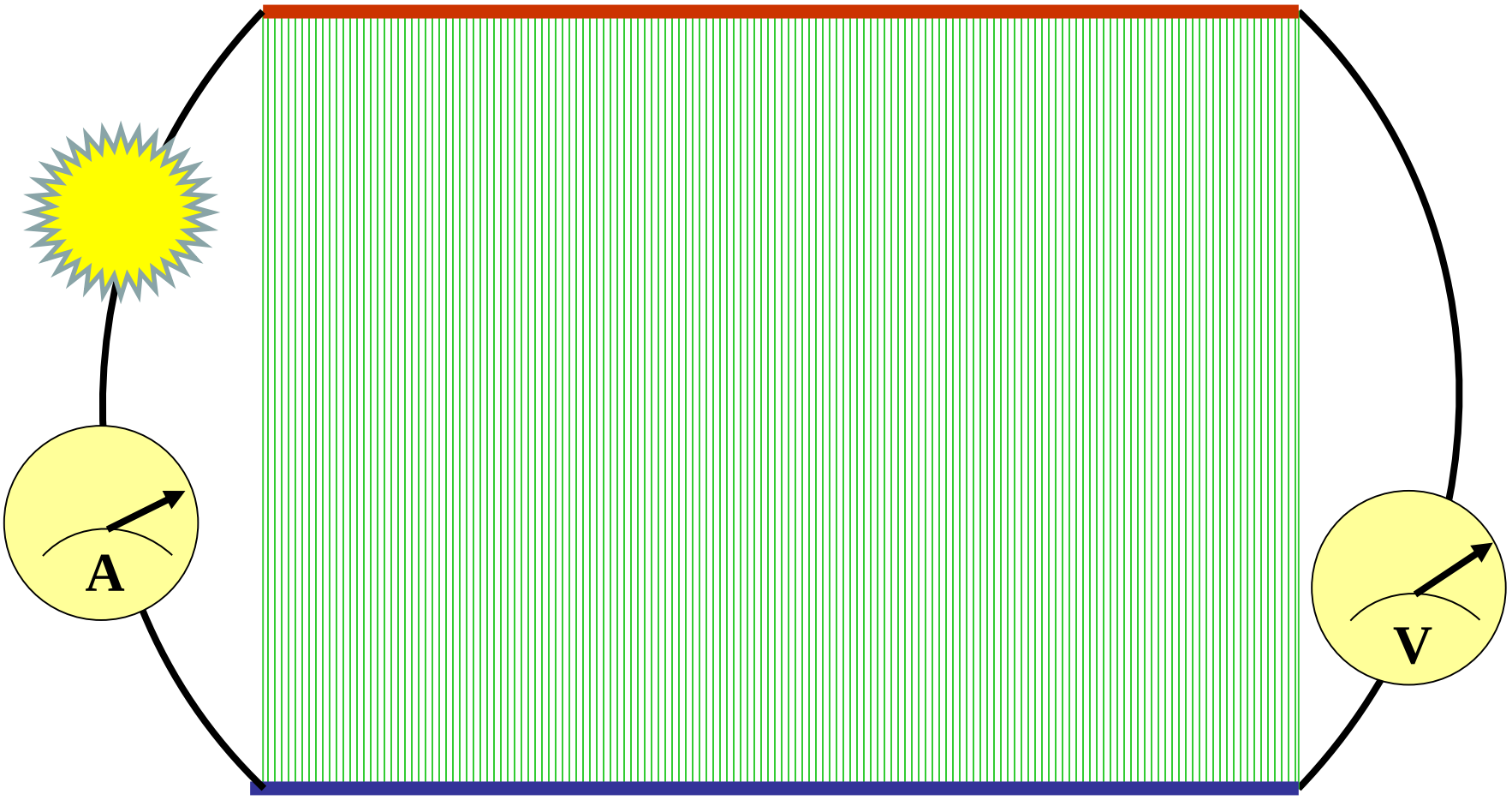
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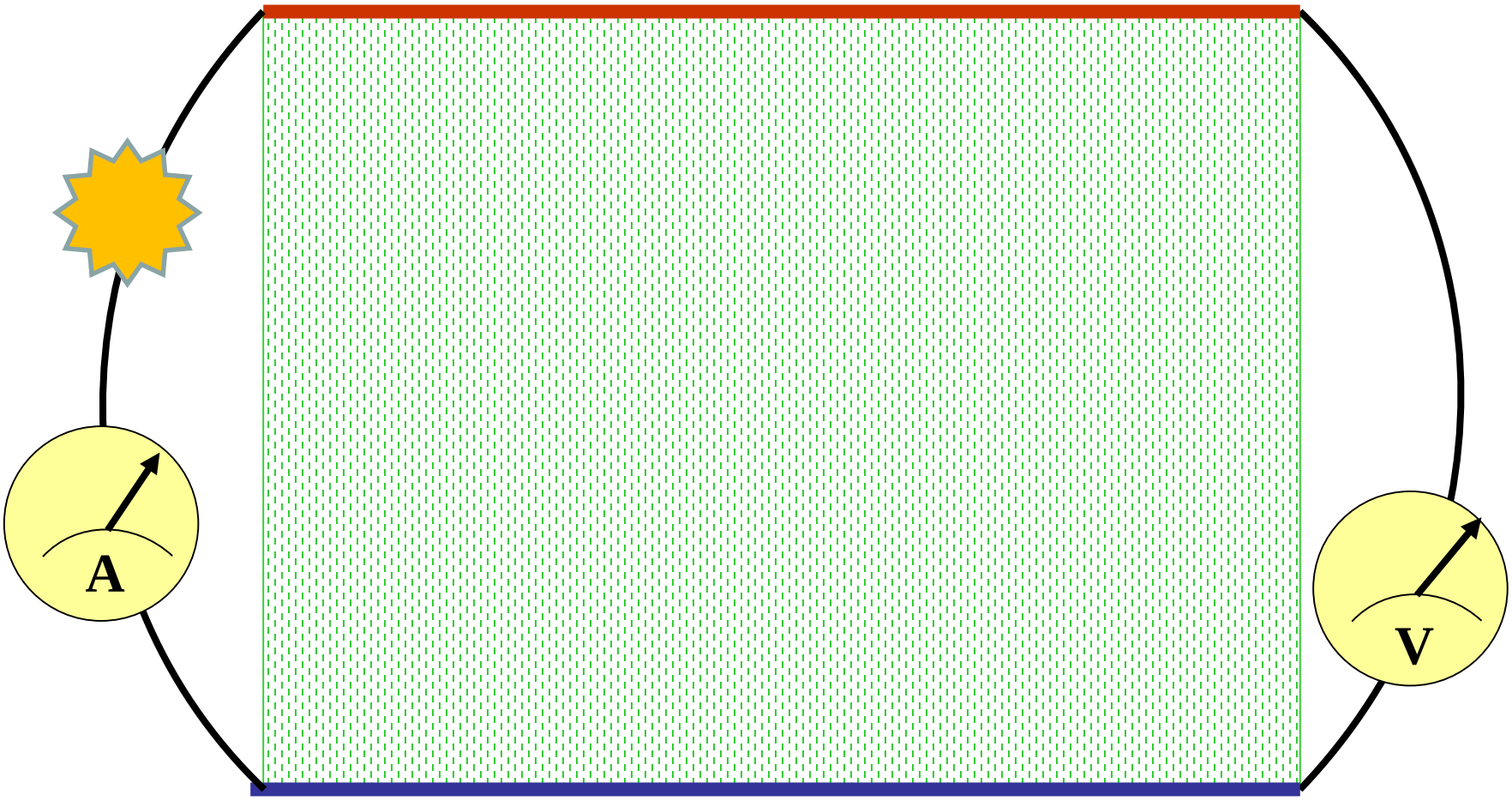
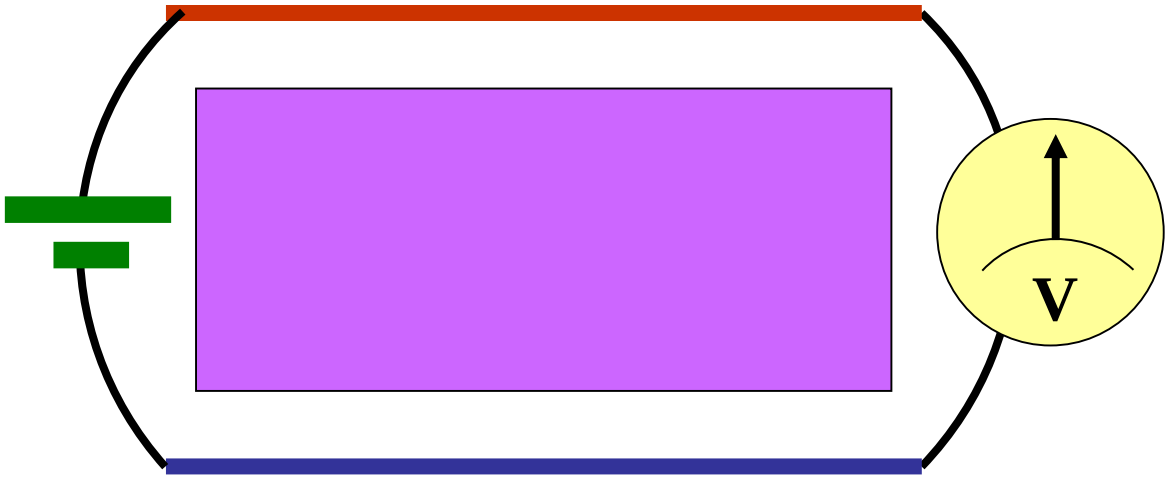
V


A
V


A
V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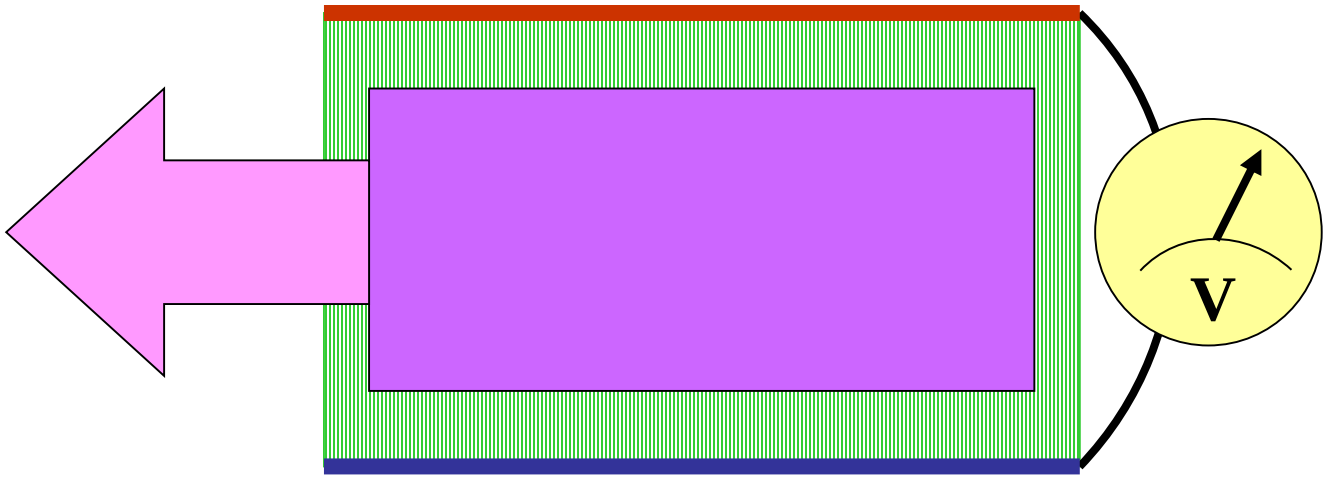
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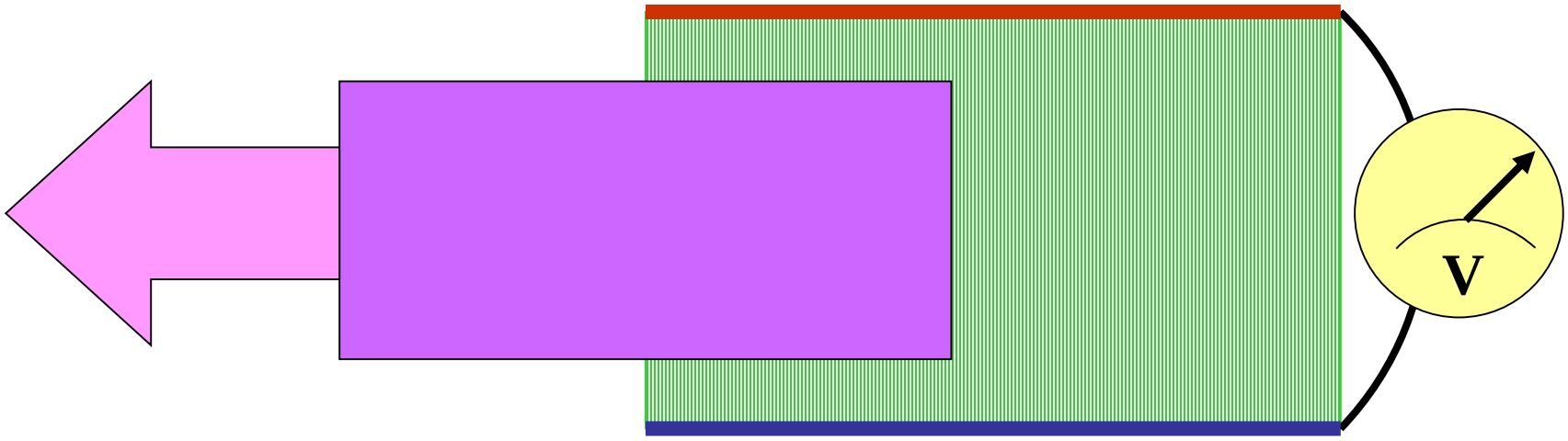
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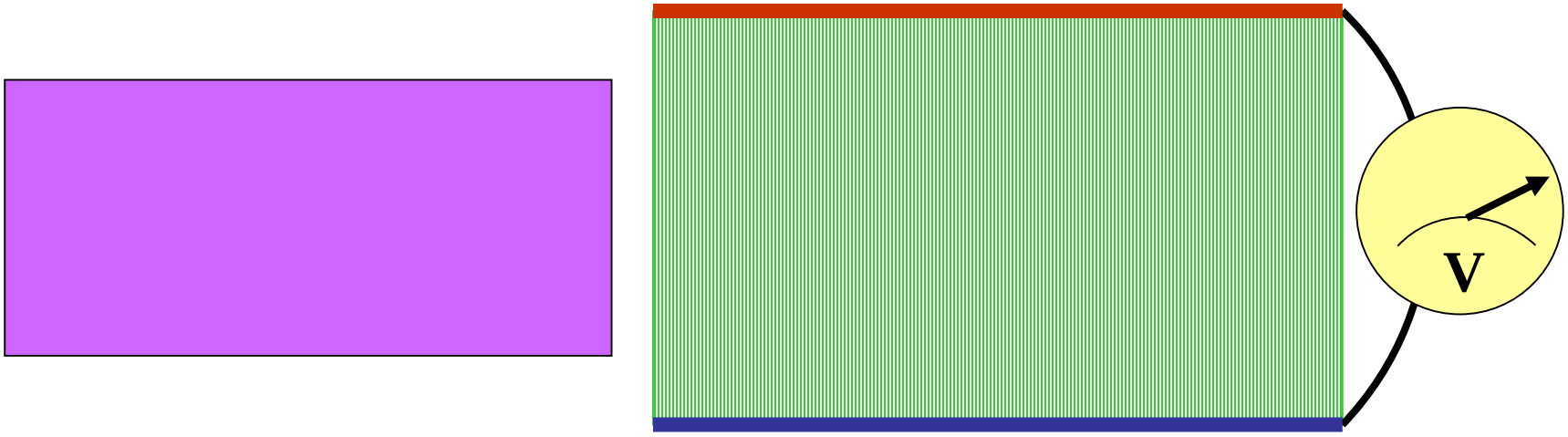
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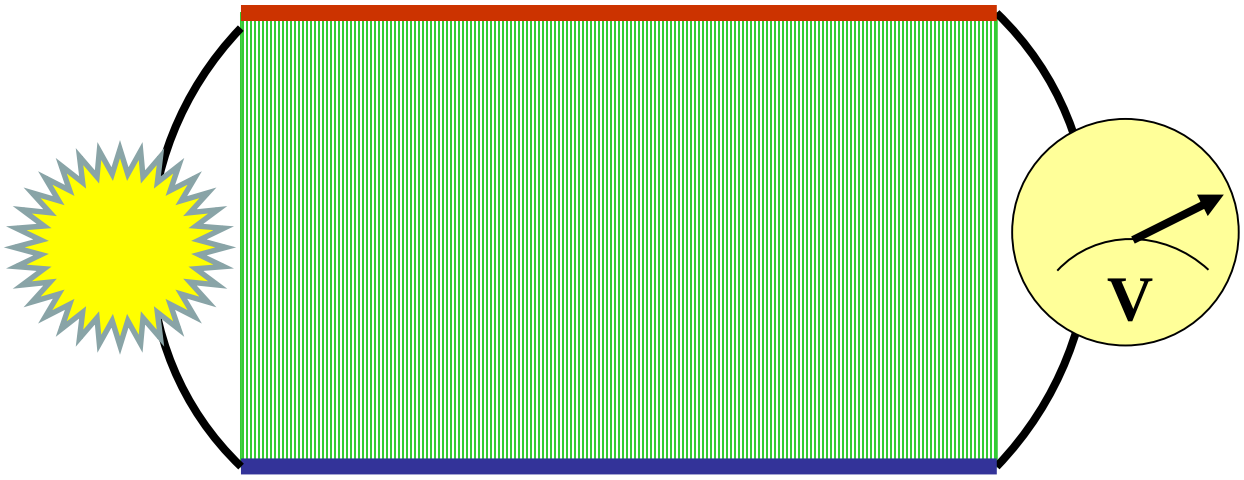
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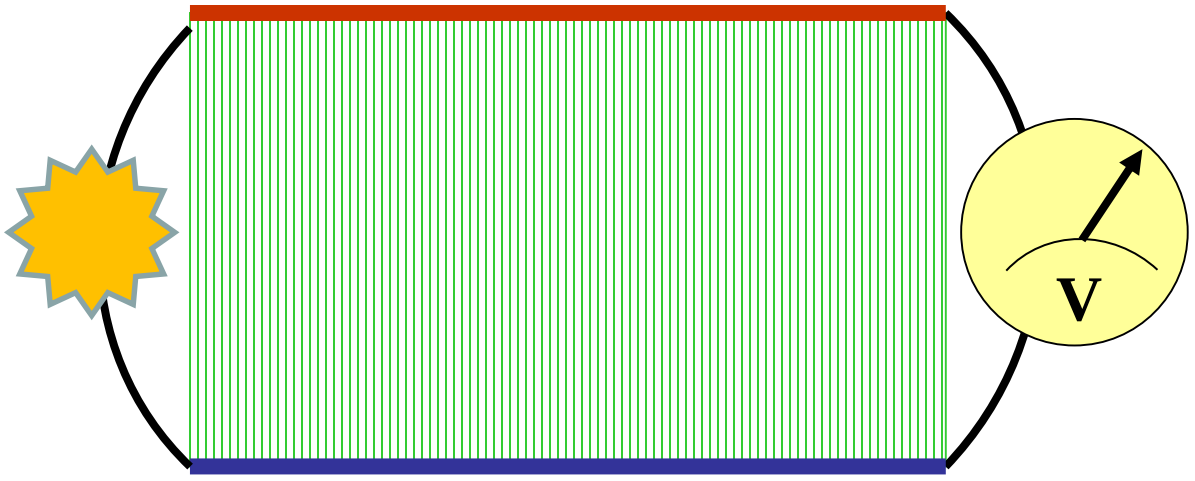
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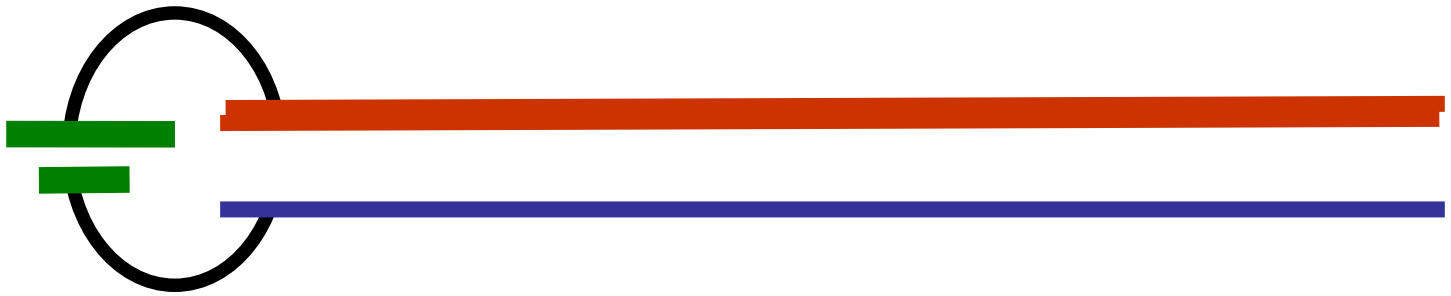

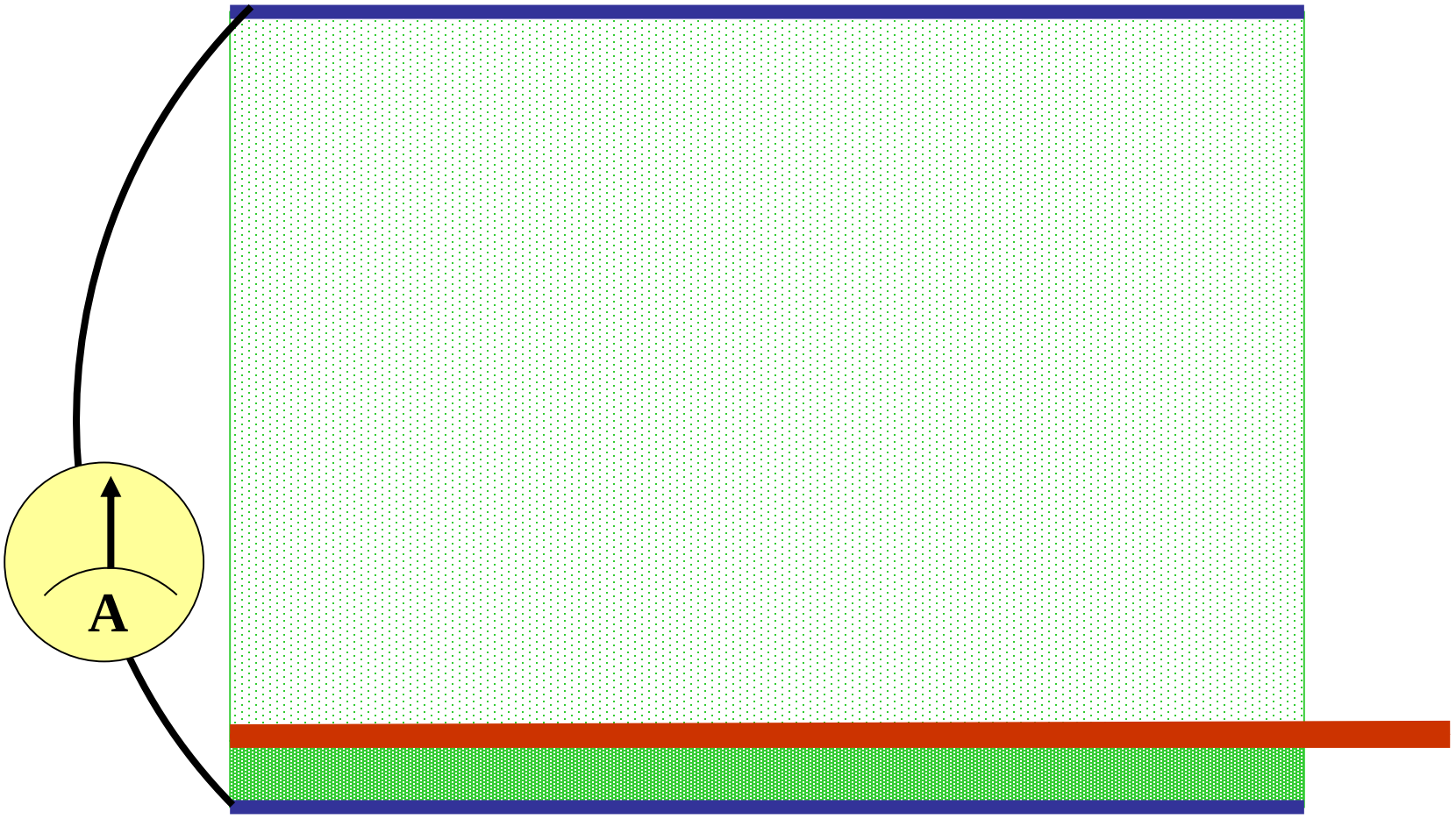
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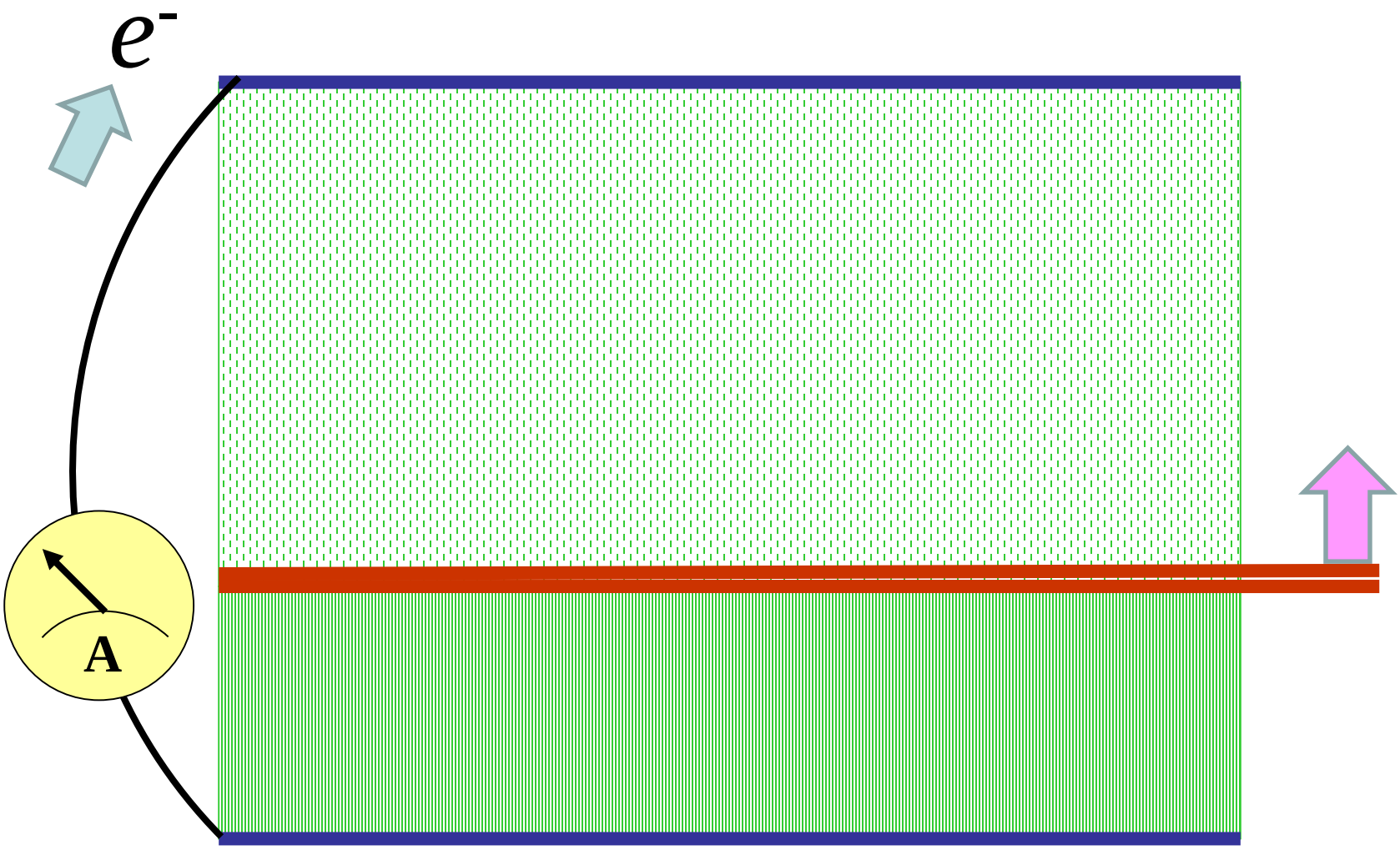
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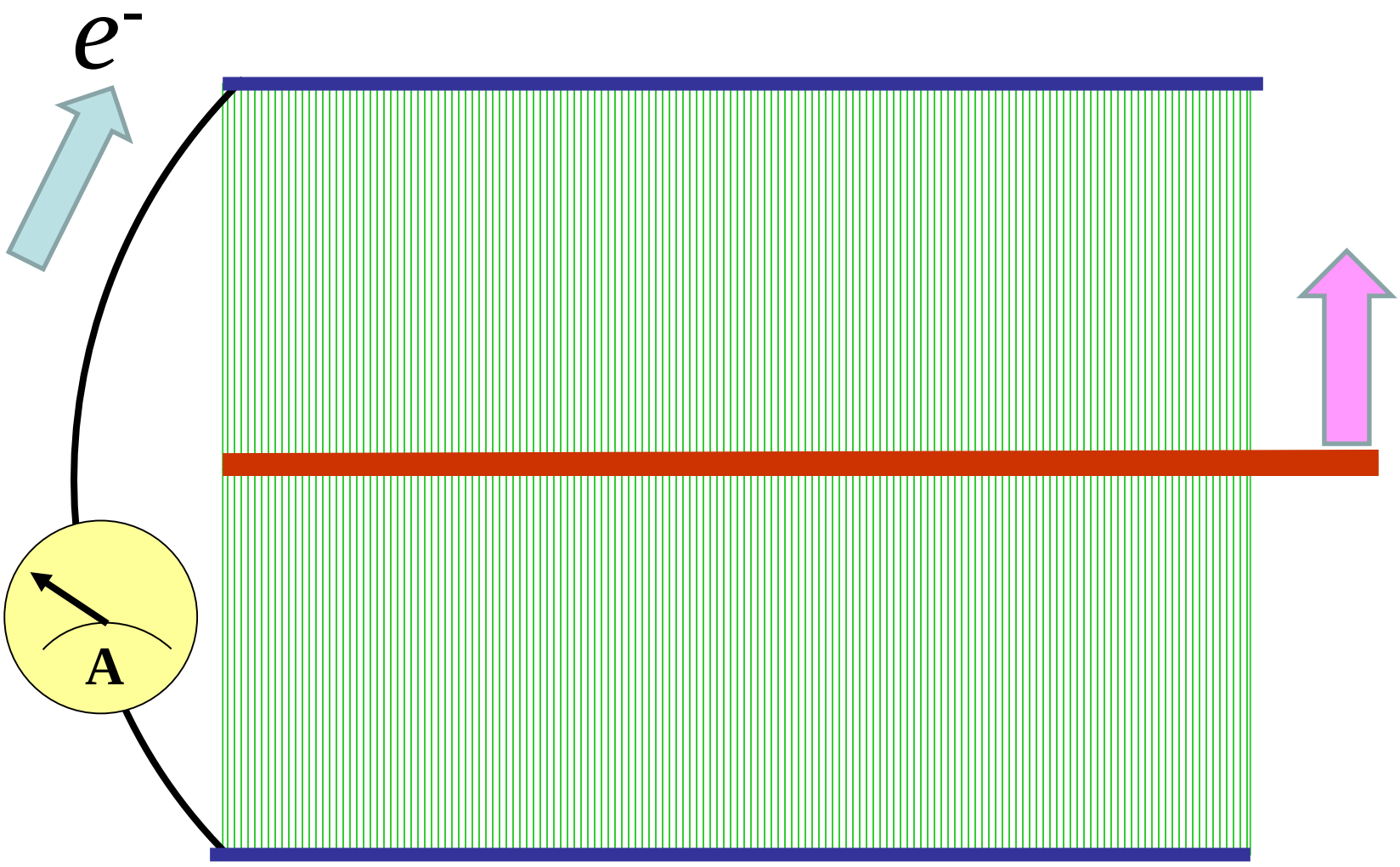
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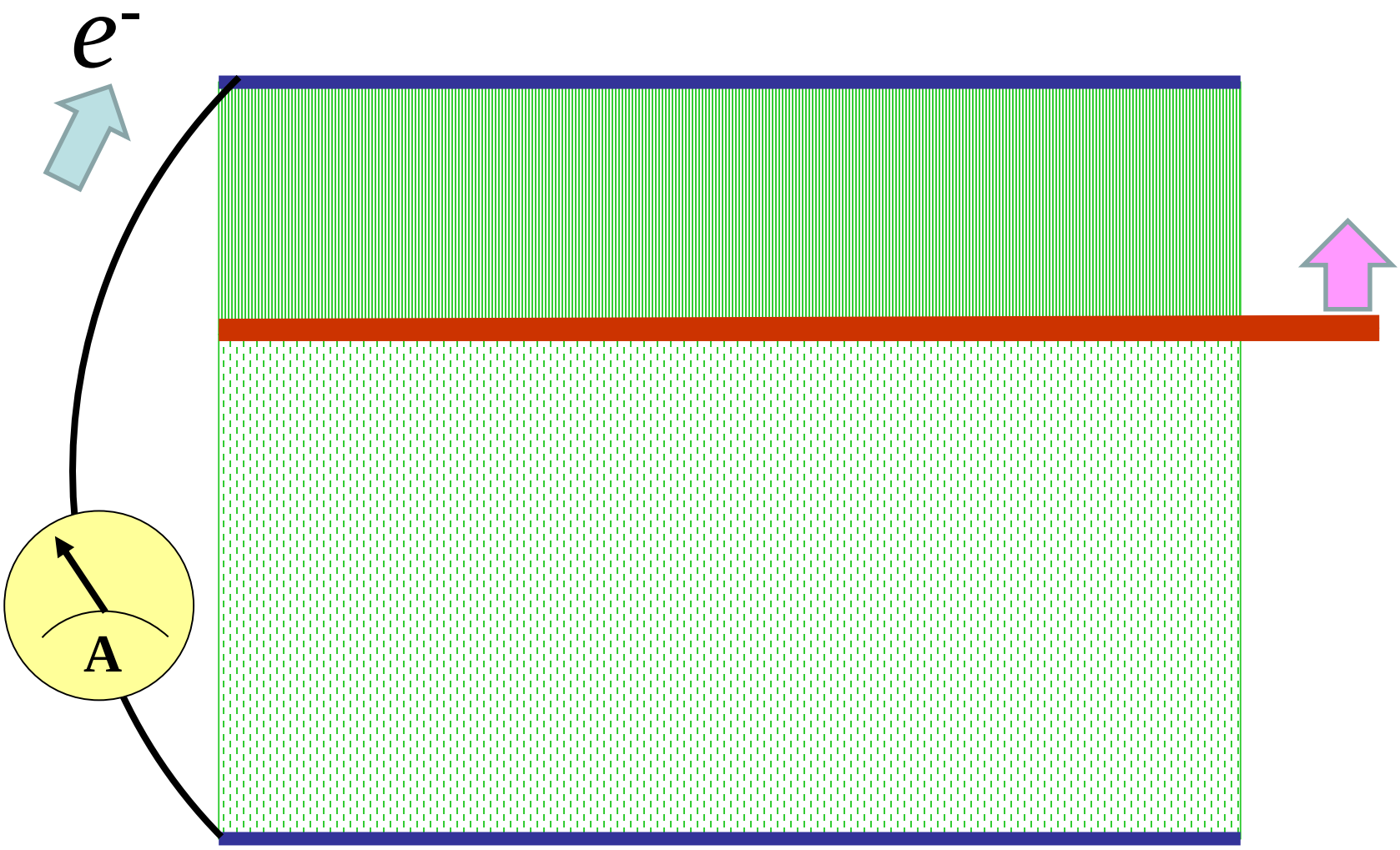
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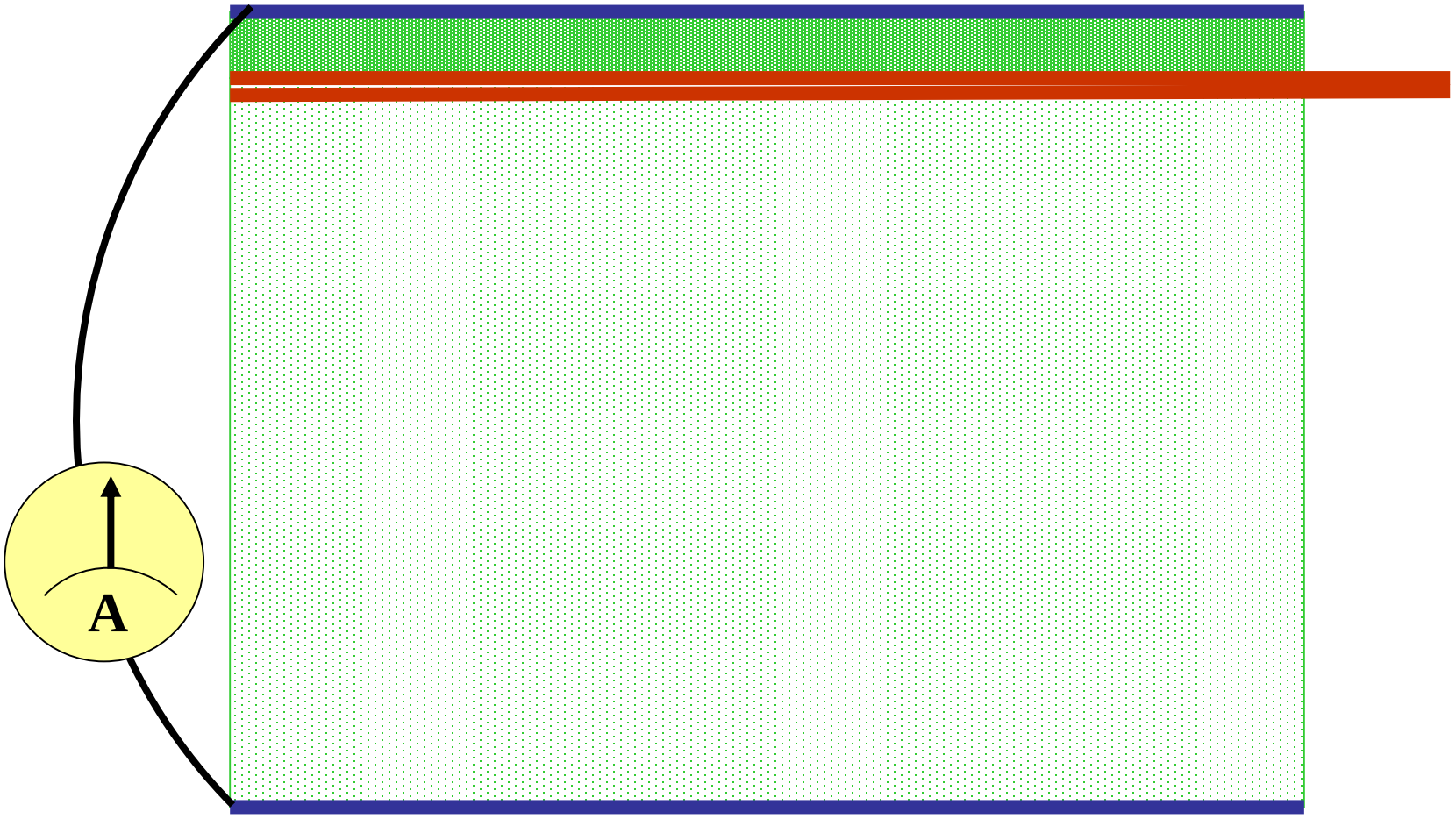
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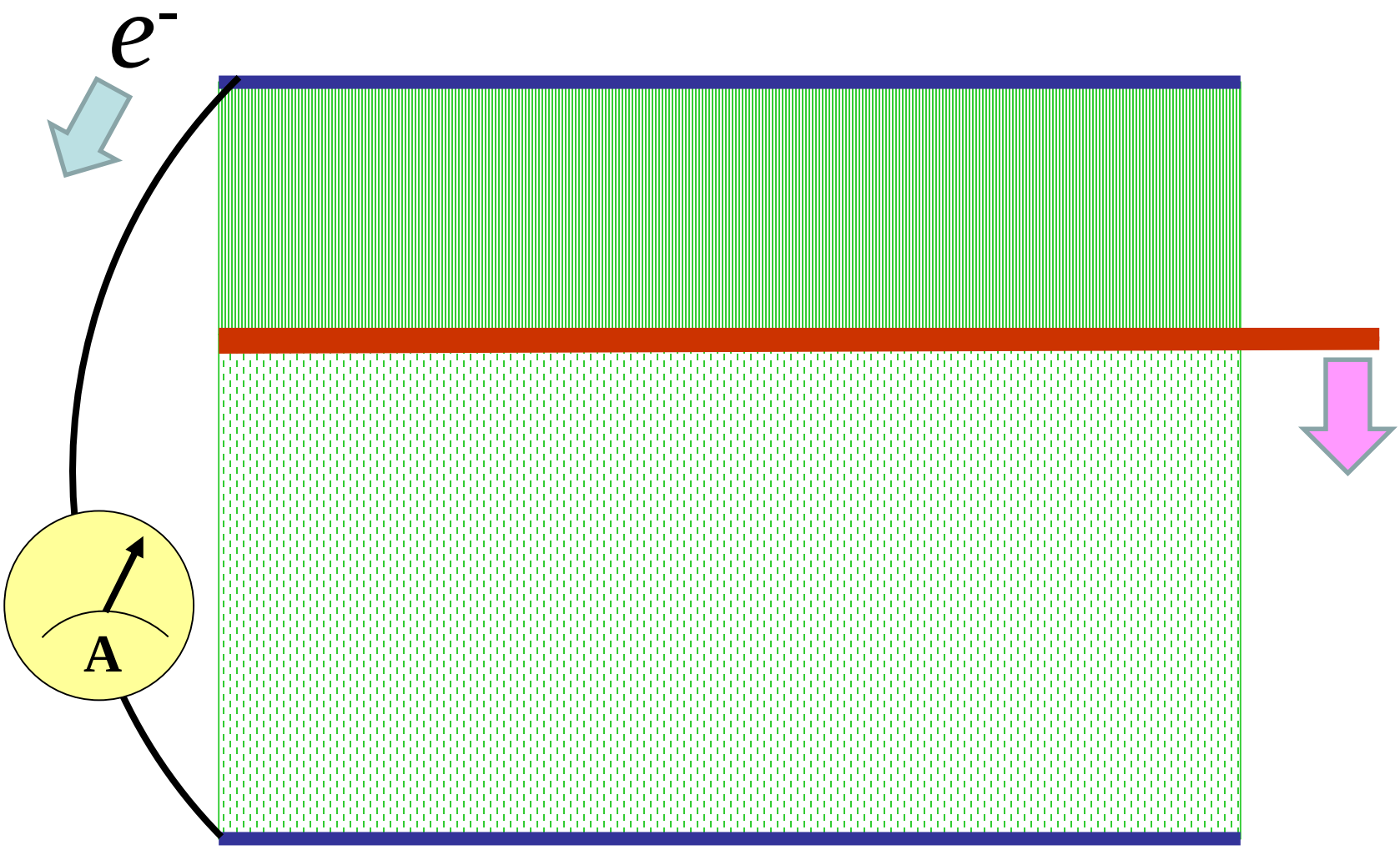
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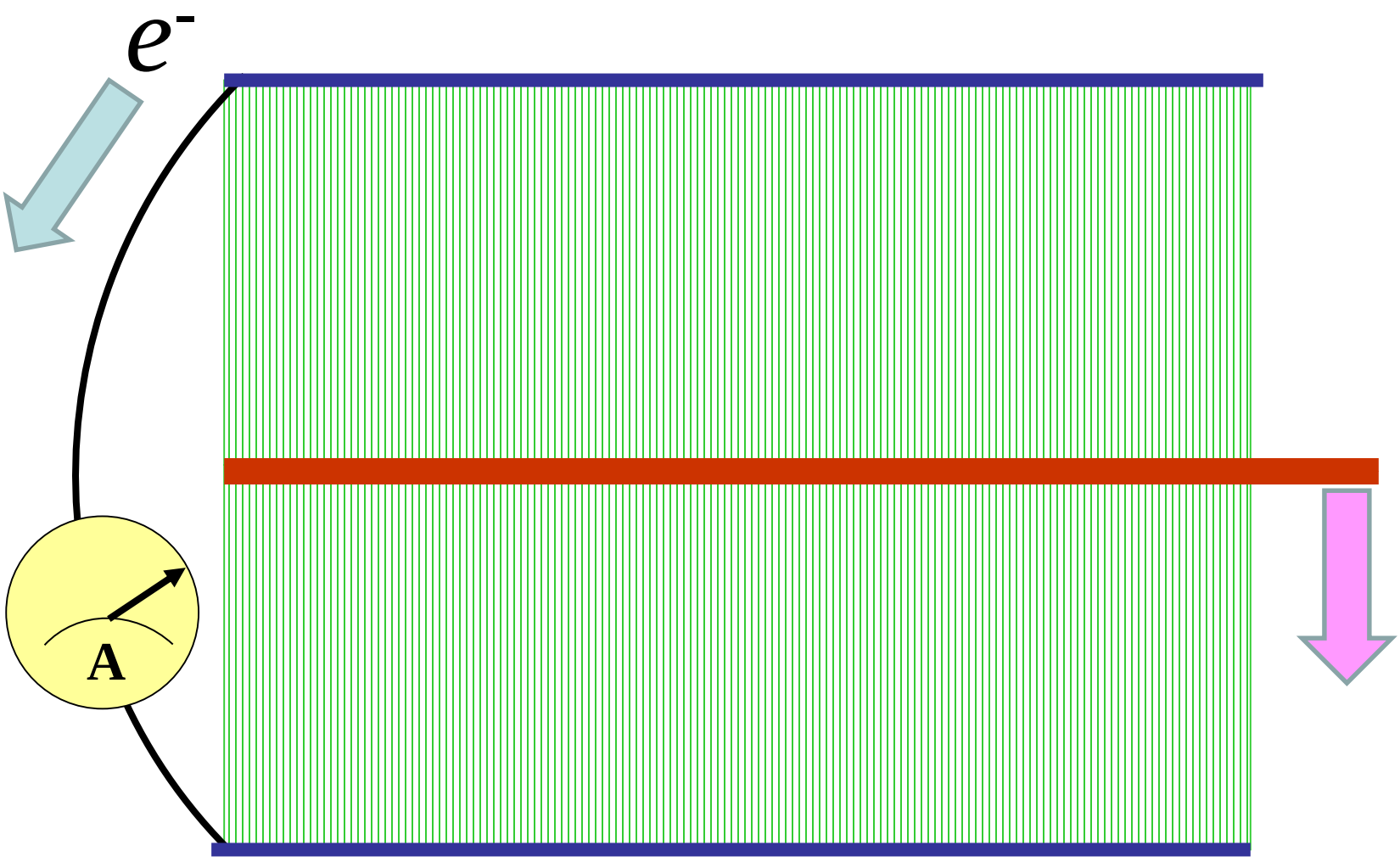
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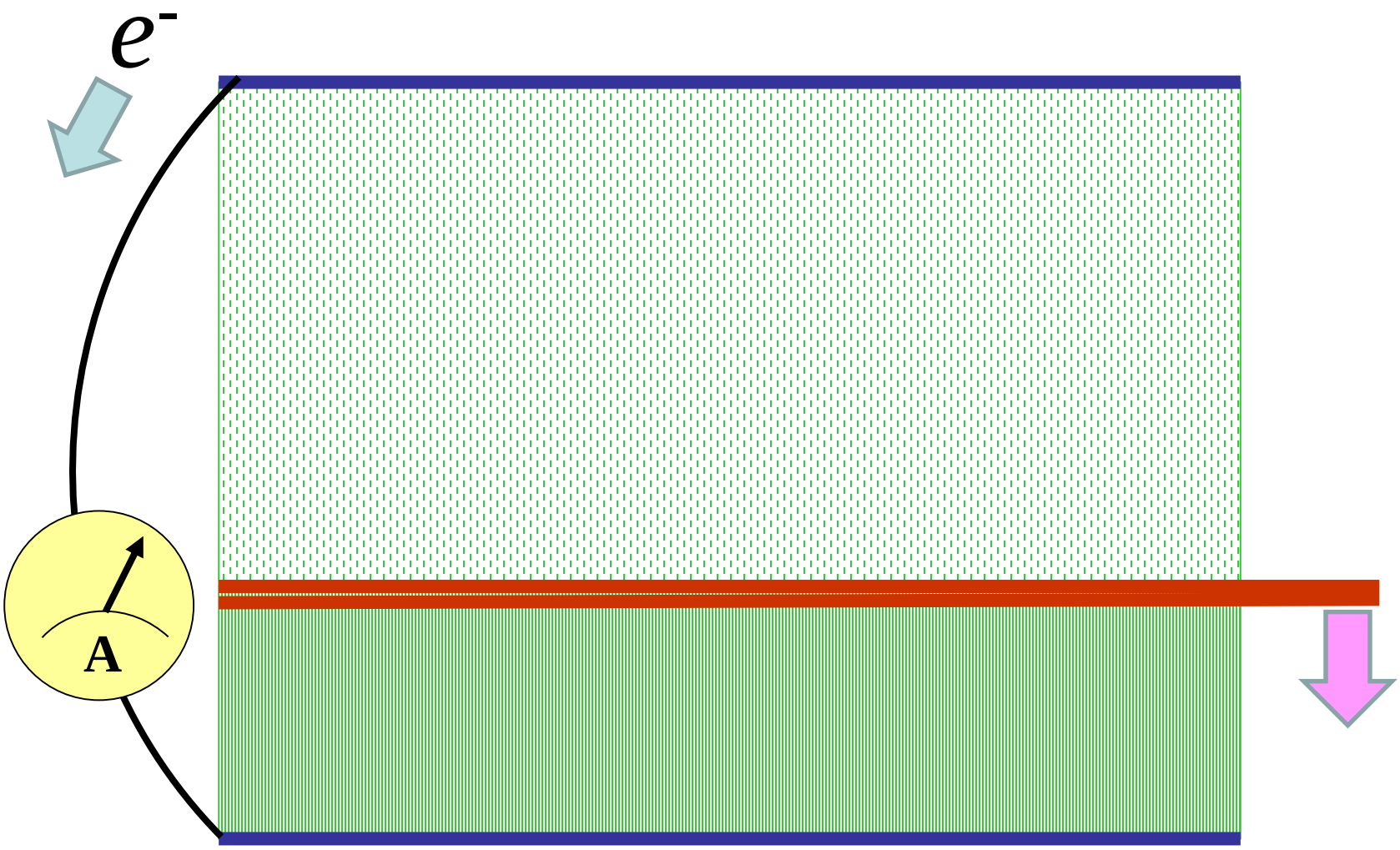
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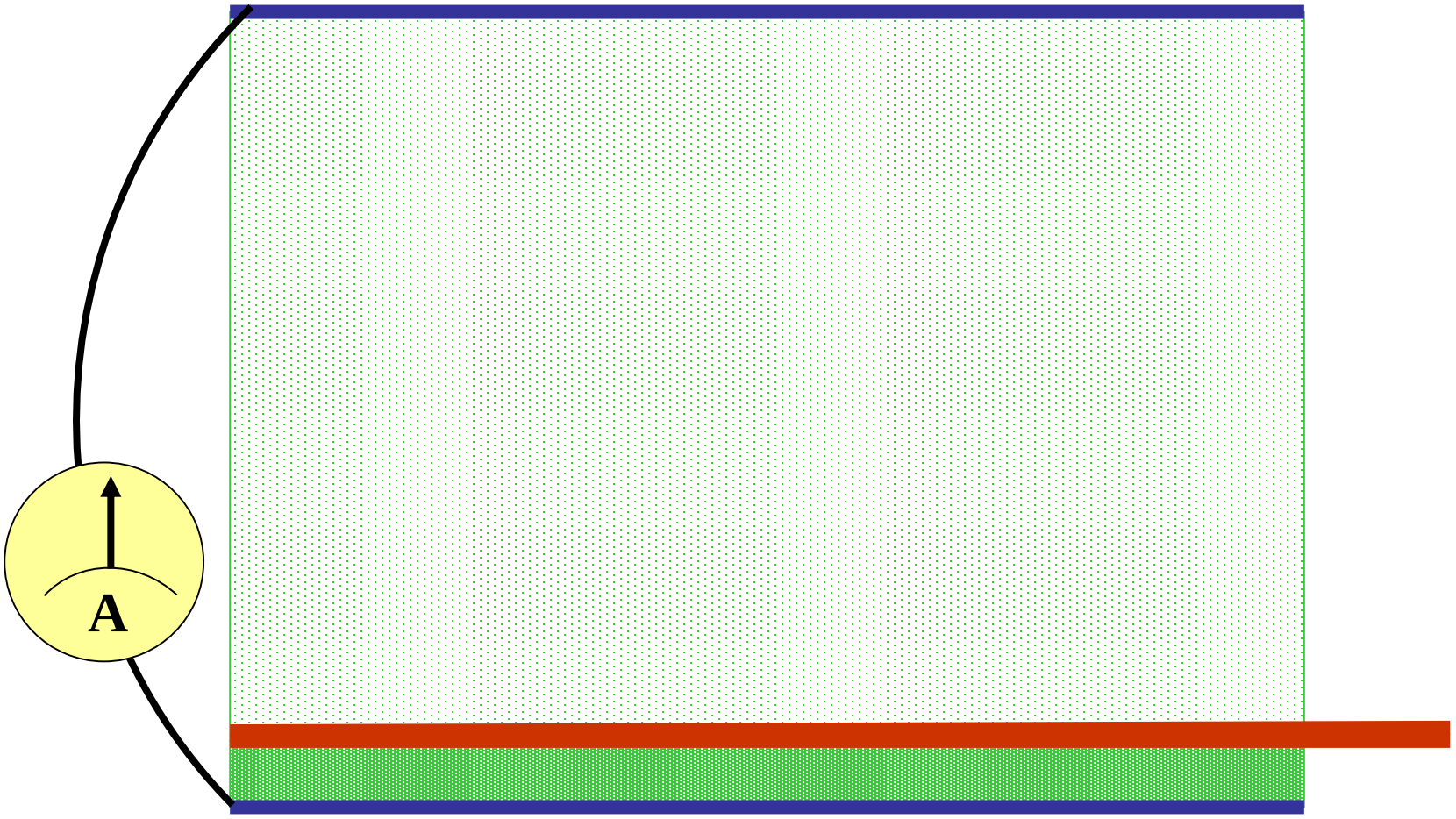
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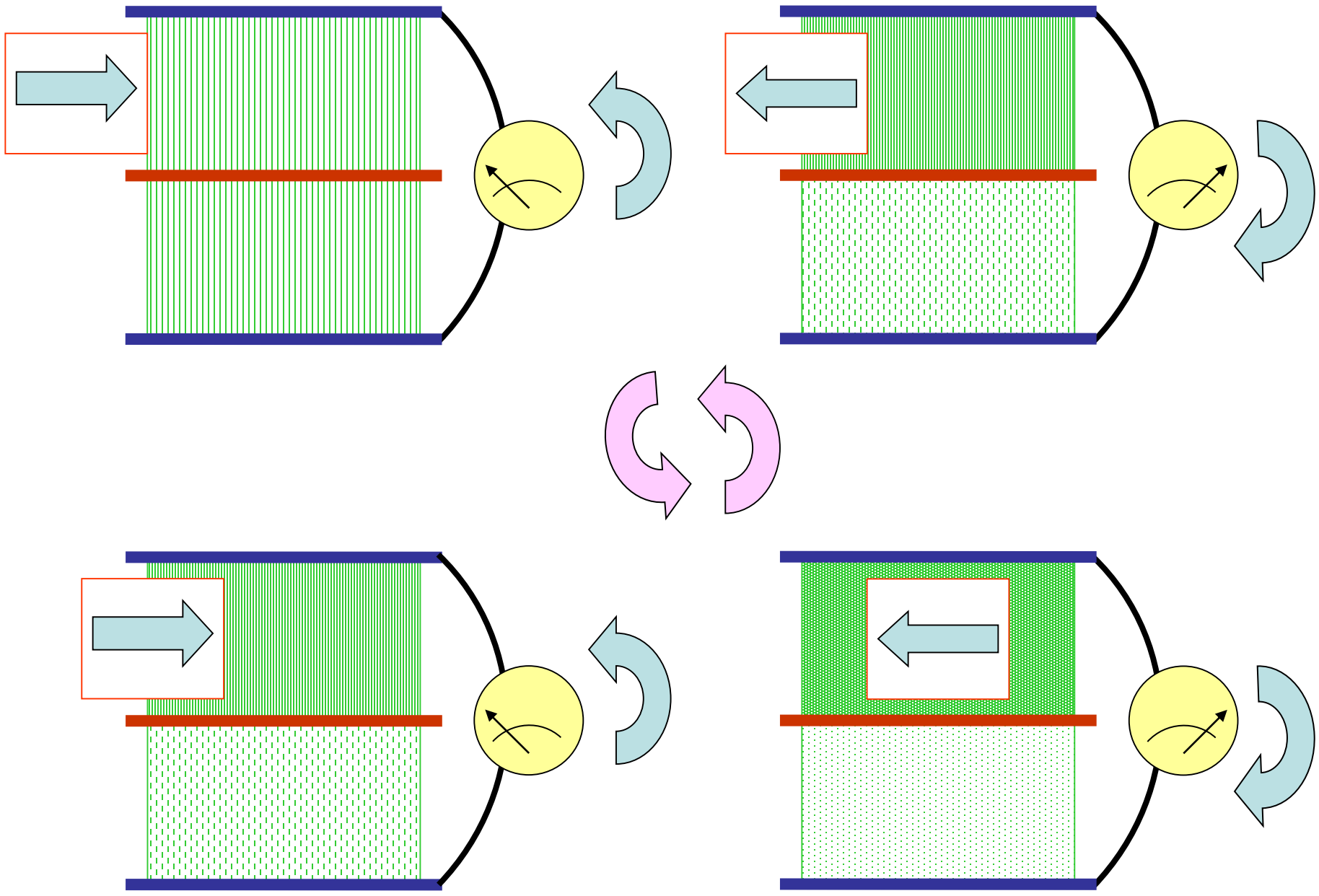
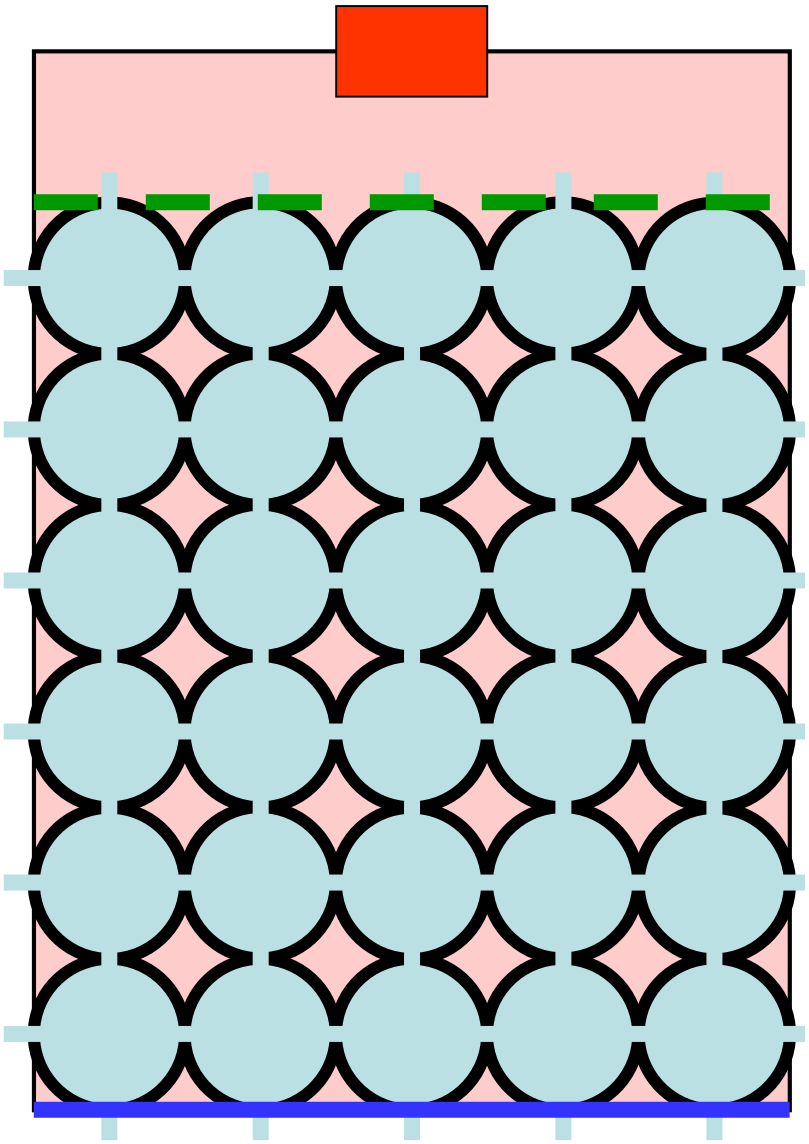
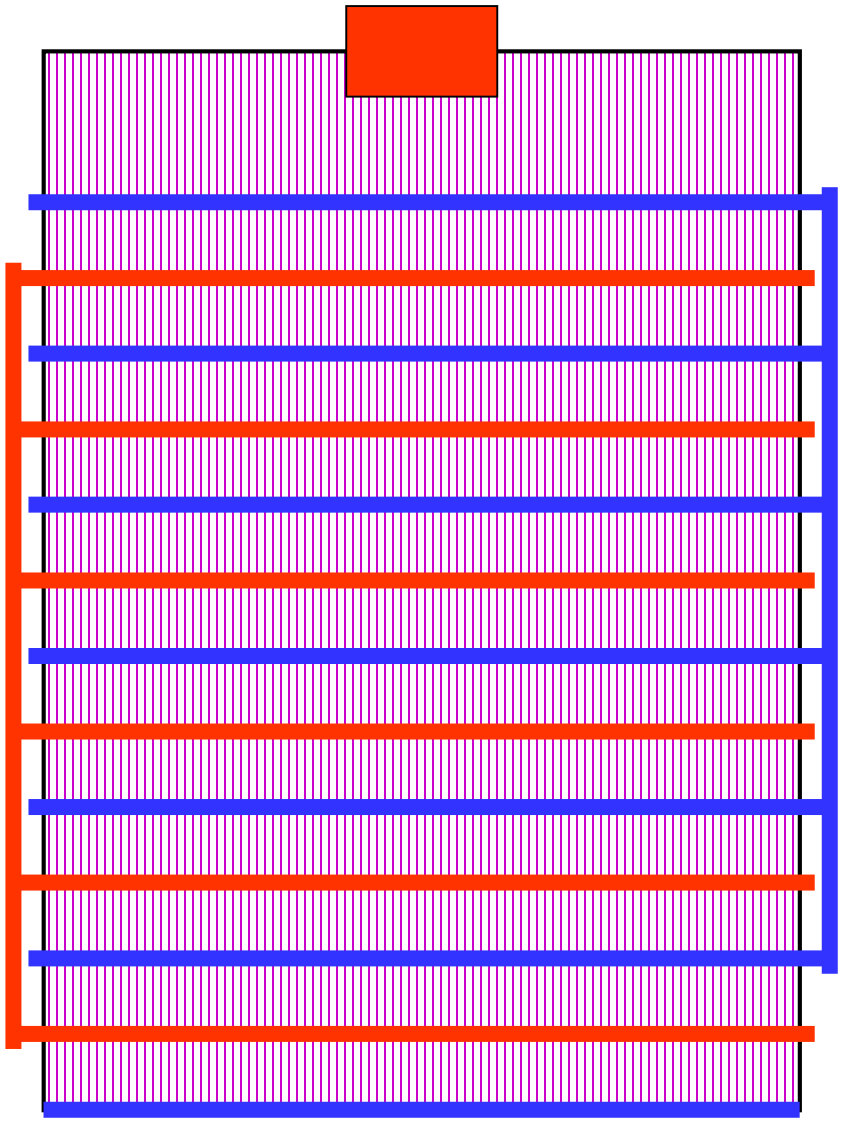






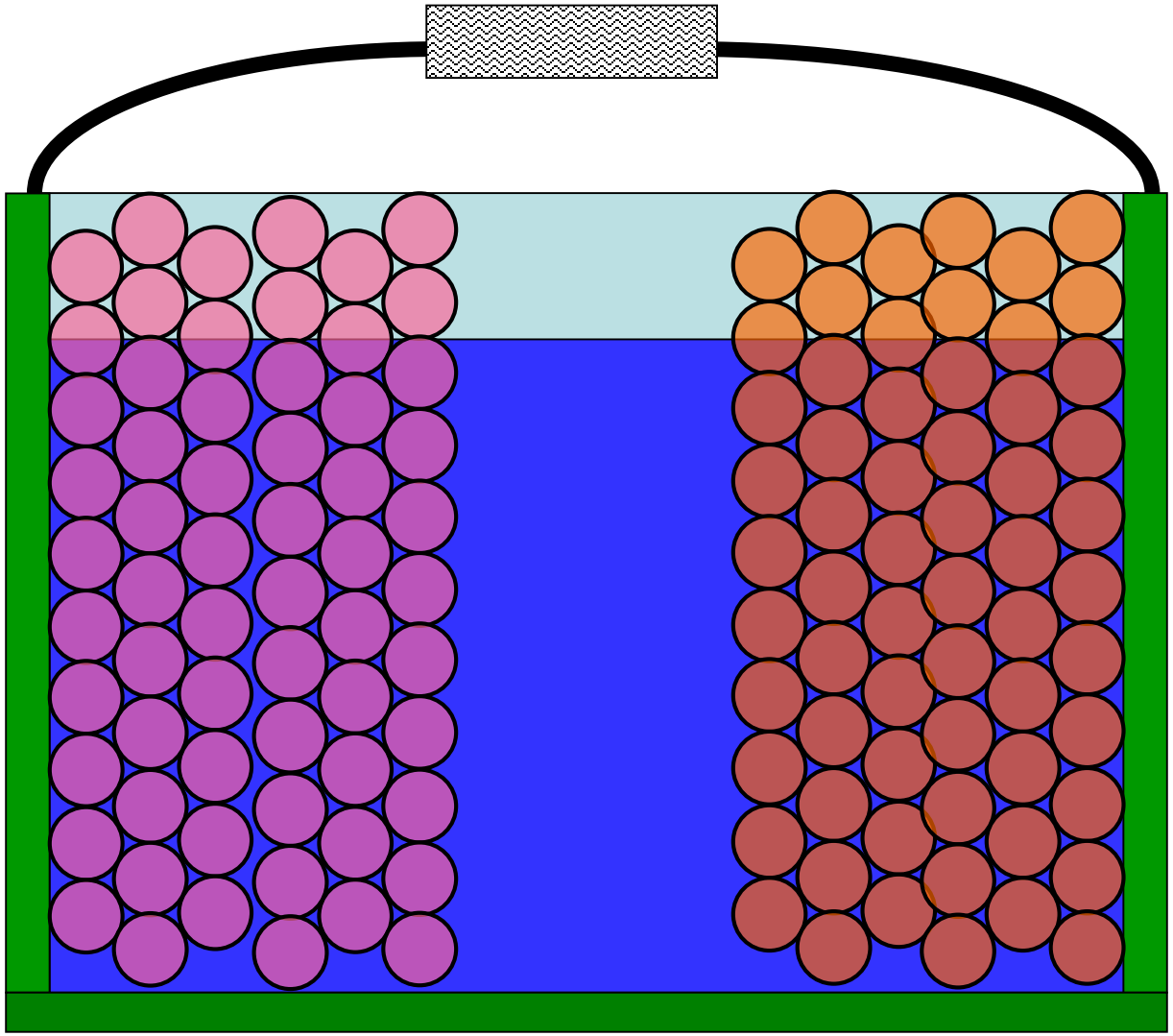
$$E = \sigma/\varepsilon_0 = Q/\varepsilon_0 A$$

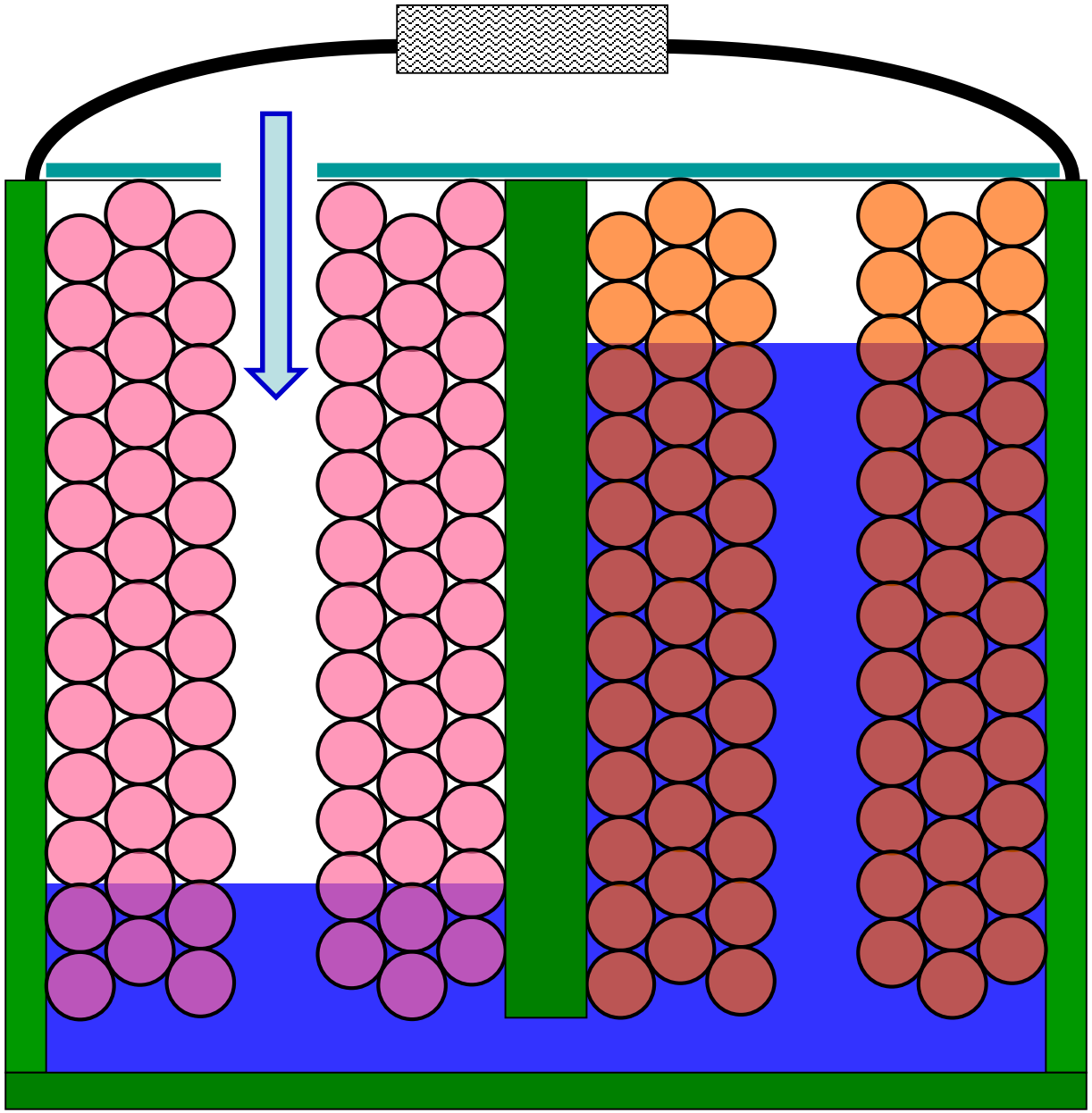
$$C \equiv Q / V = \varepsilon_0 A / d$$

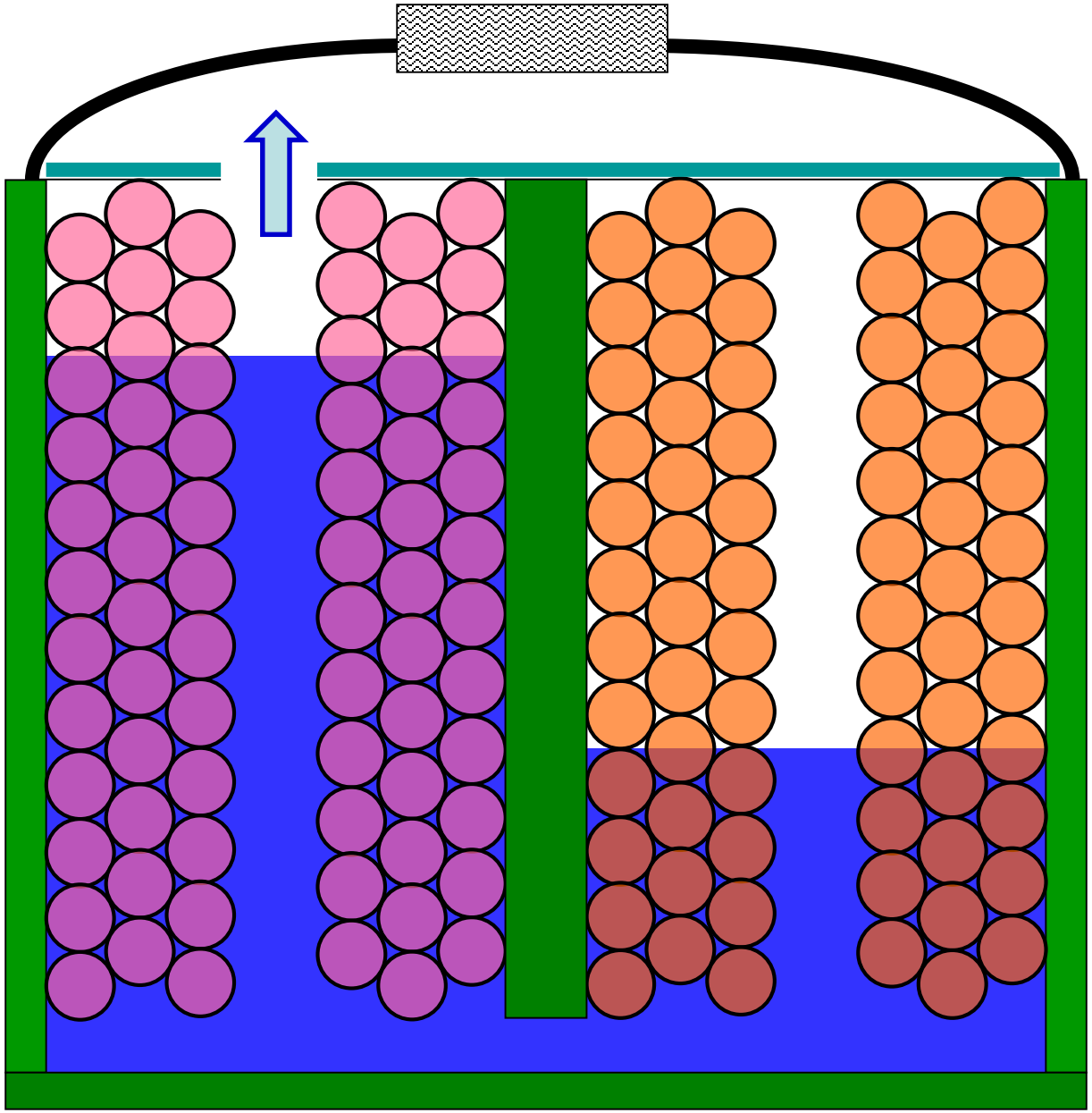
$$V = E d$$

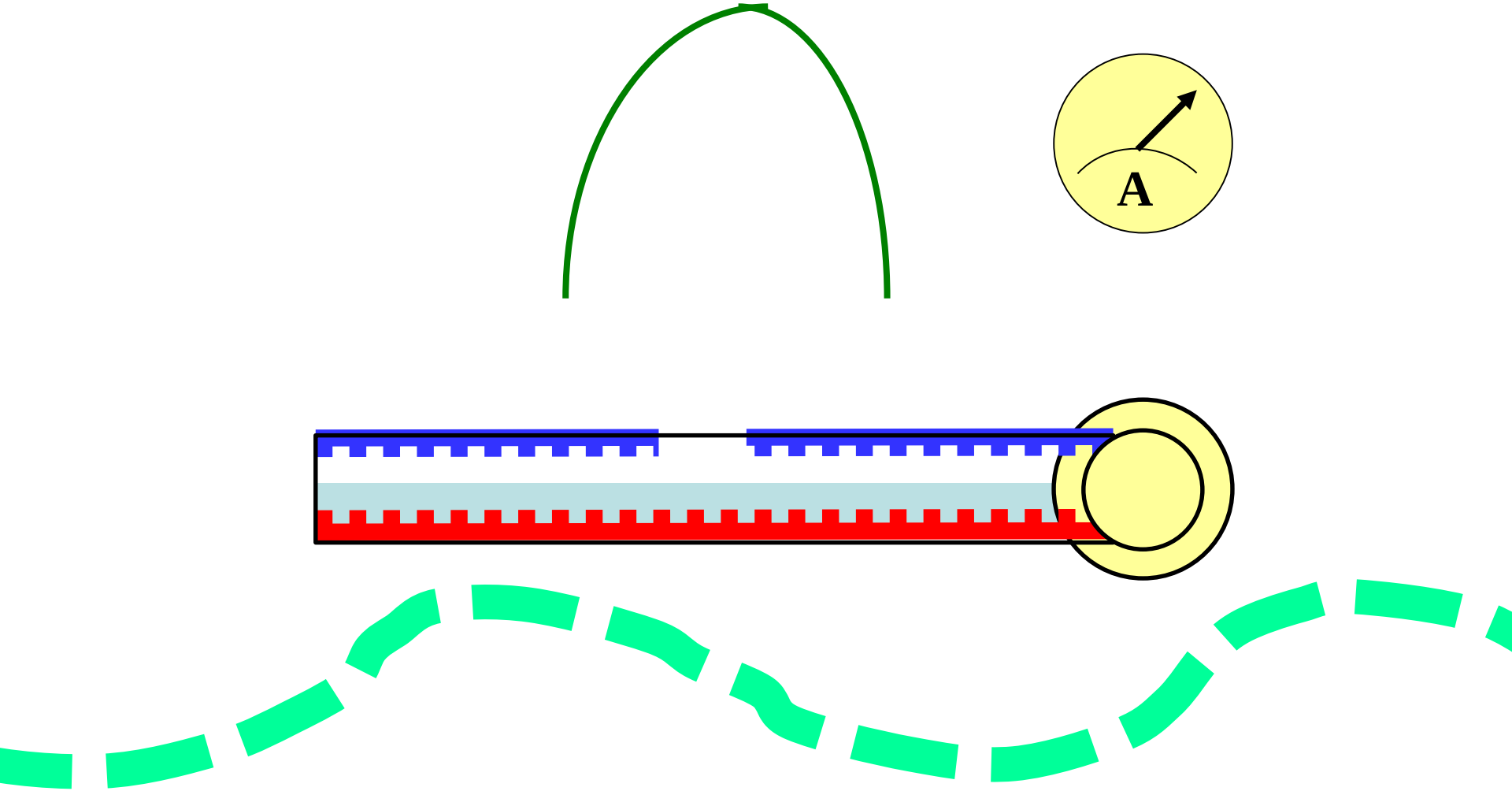
$$\frac{C_r}{C_d} \sim \frac{\kappa_t \varepsilon_0 \, 4\pi r^2 / t}{\kappa \varepsilon_0 \, 2 (2r)^2 / r} = \frac{\pi r}{2 t}$$

Super-capacitor





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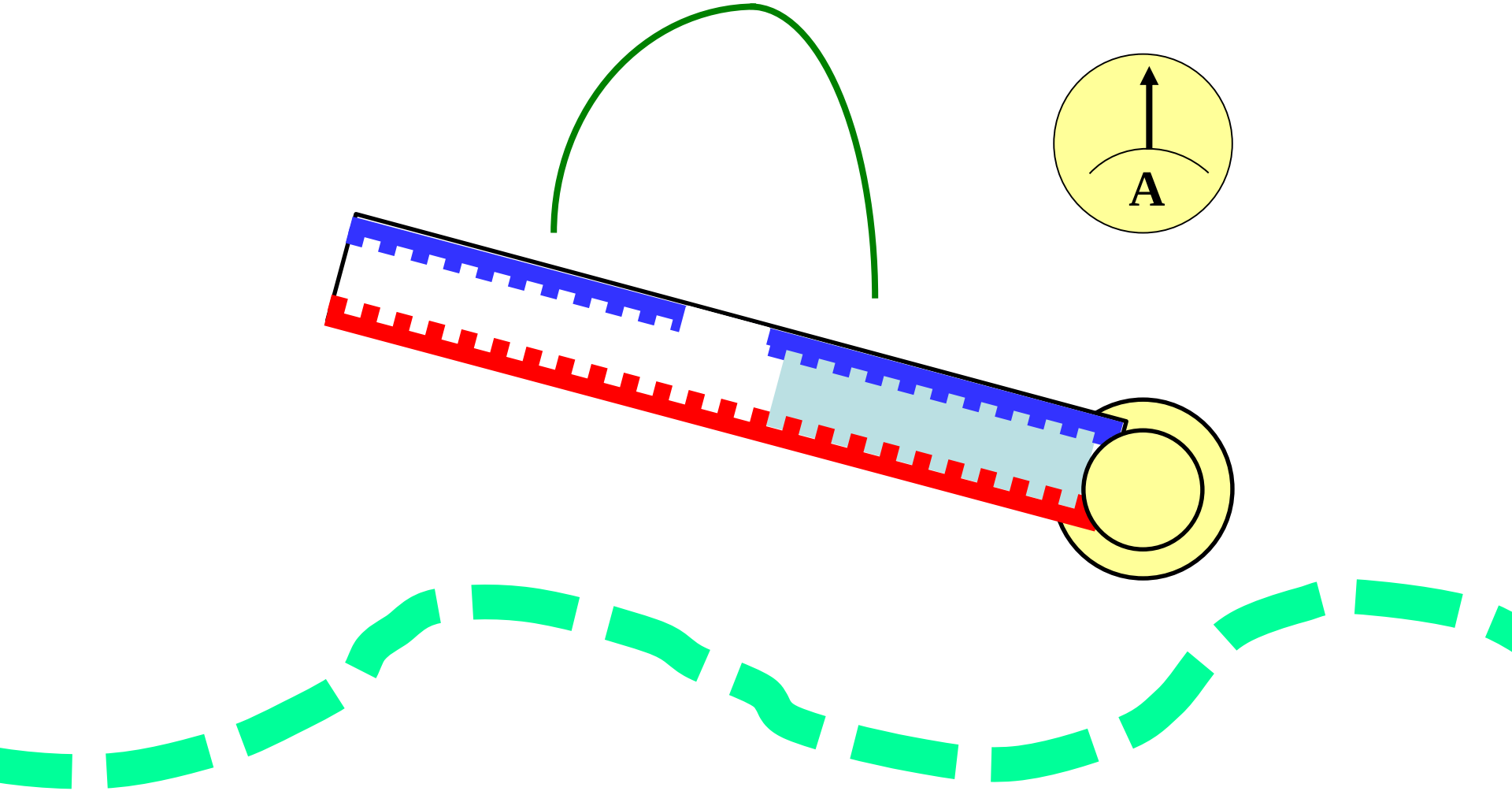
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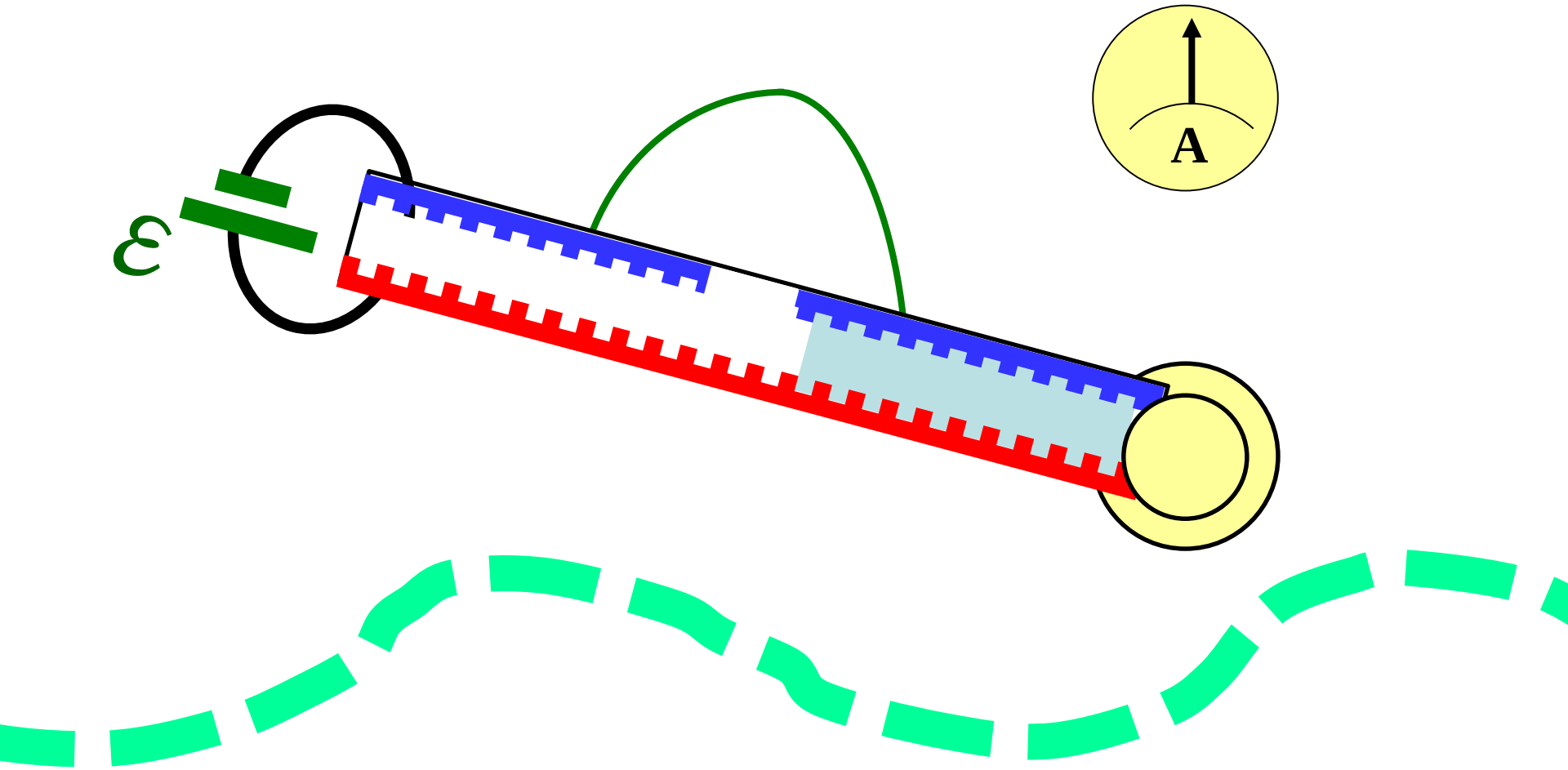
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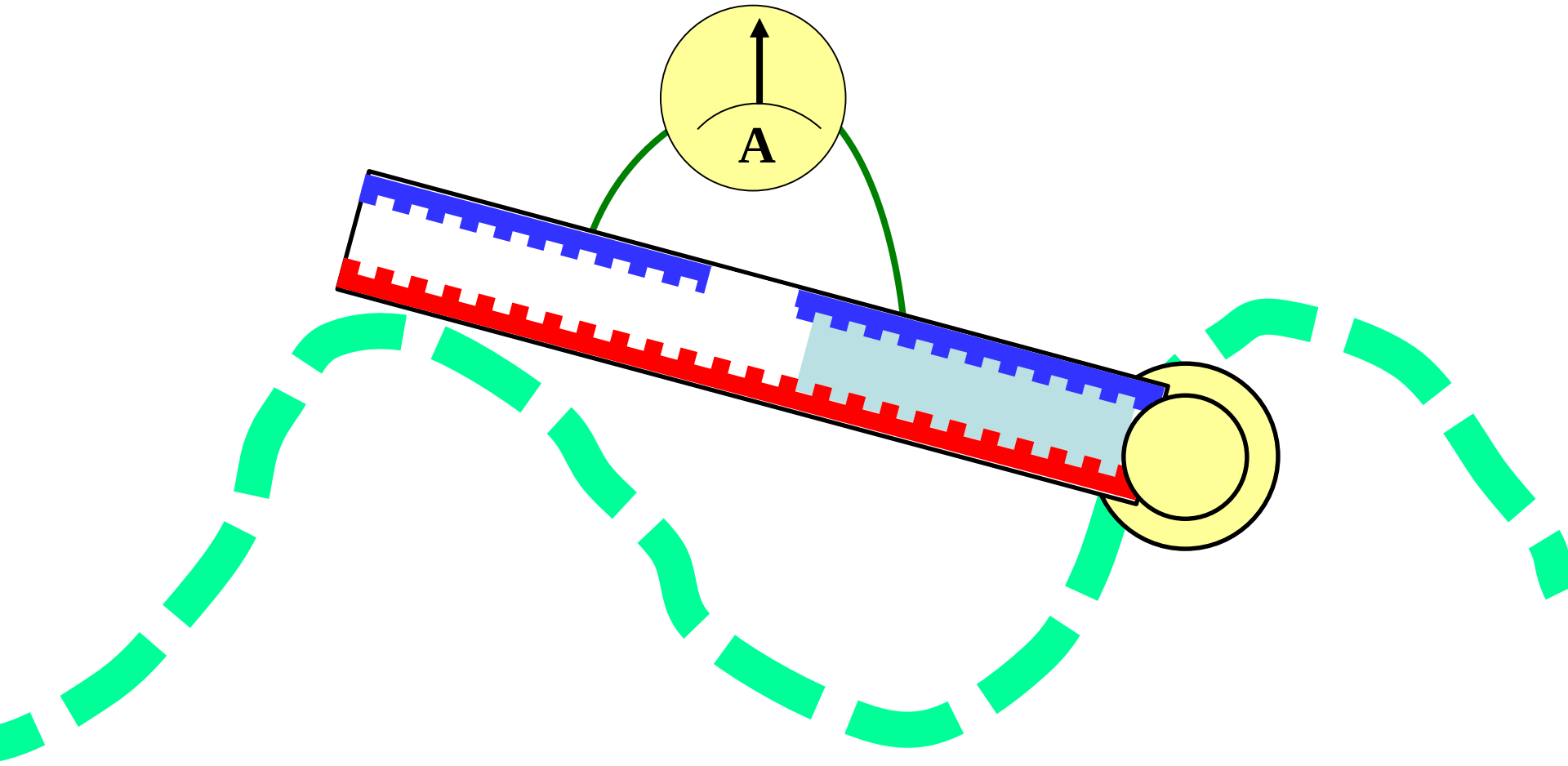
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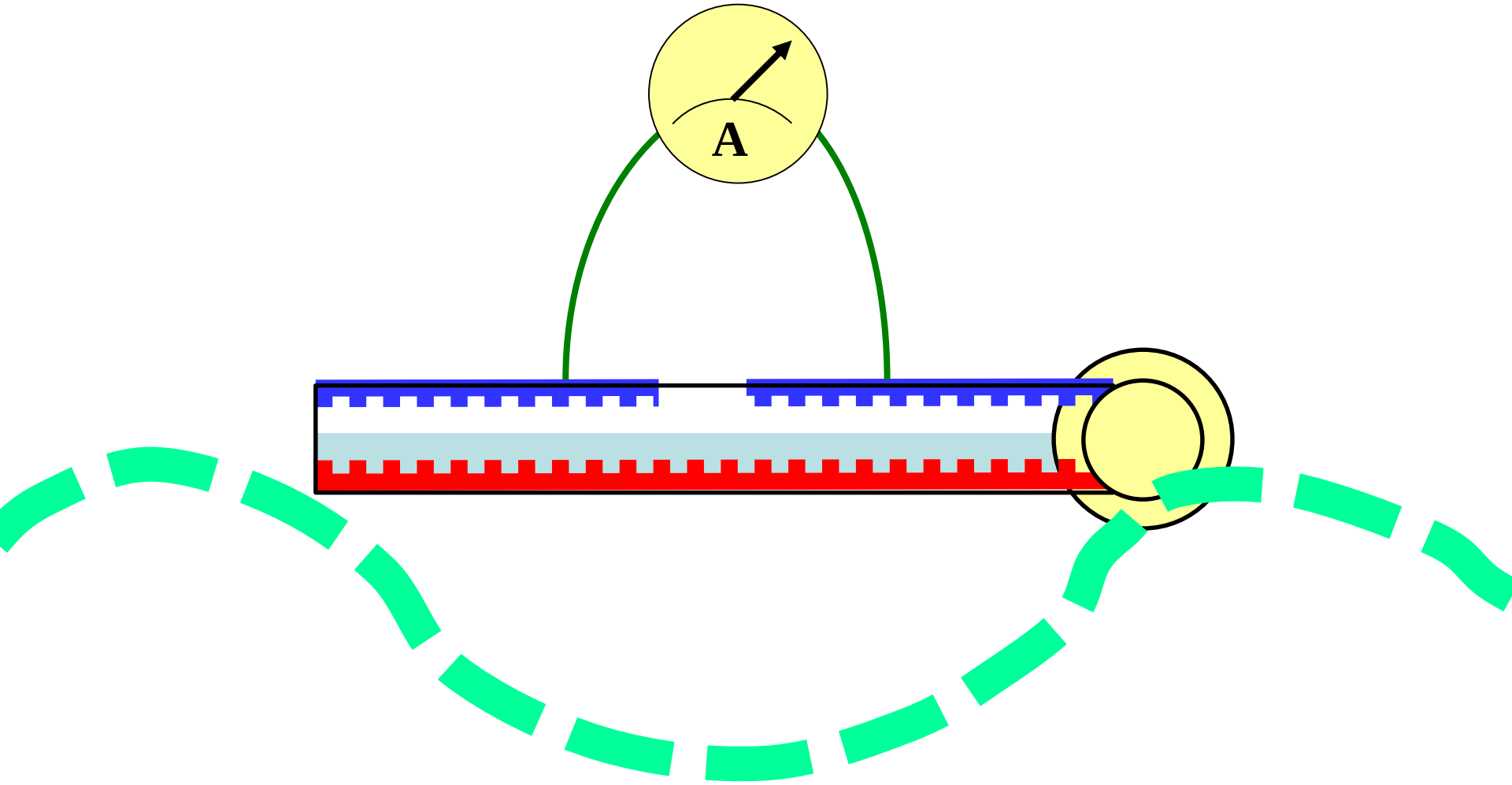
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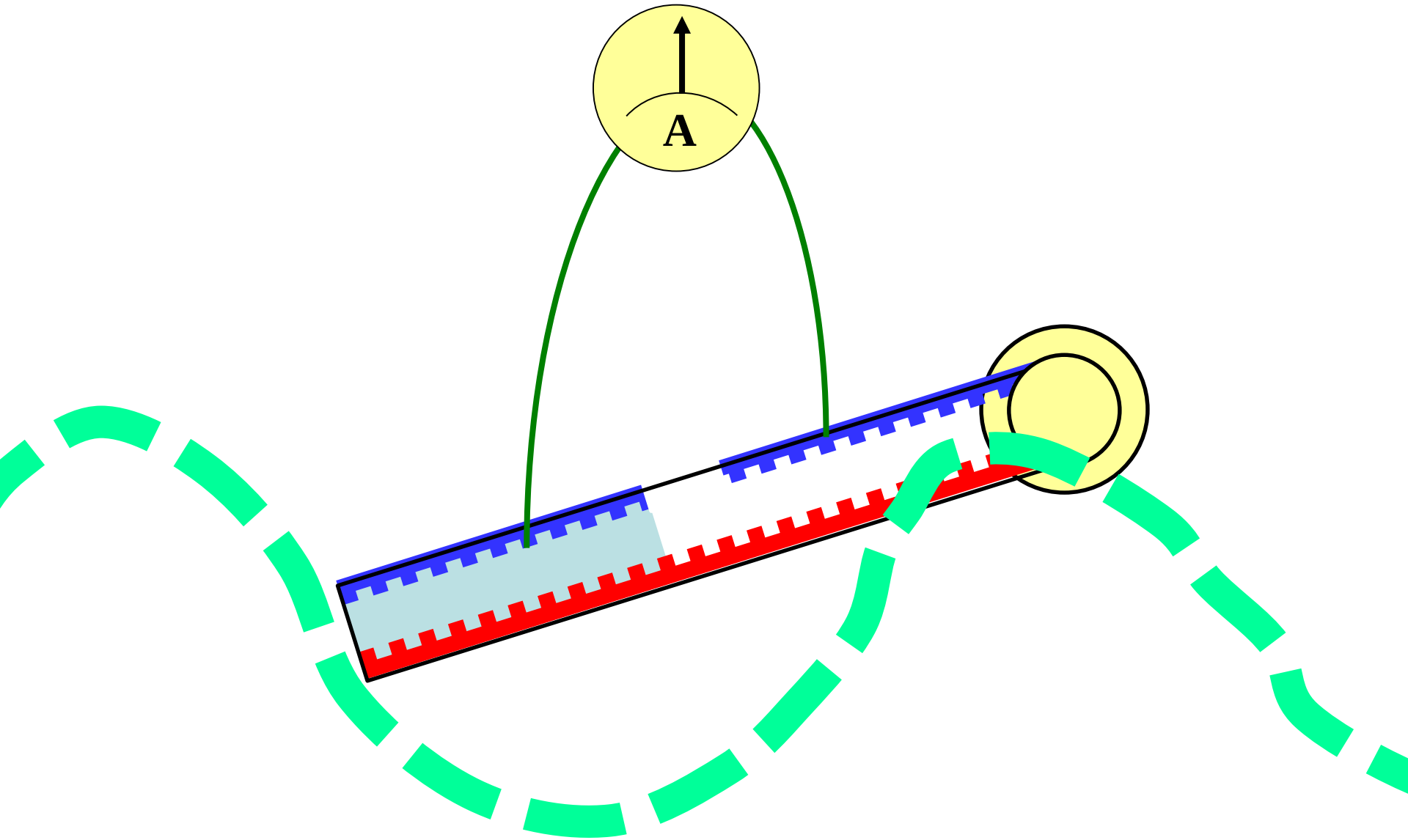
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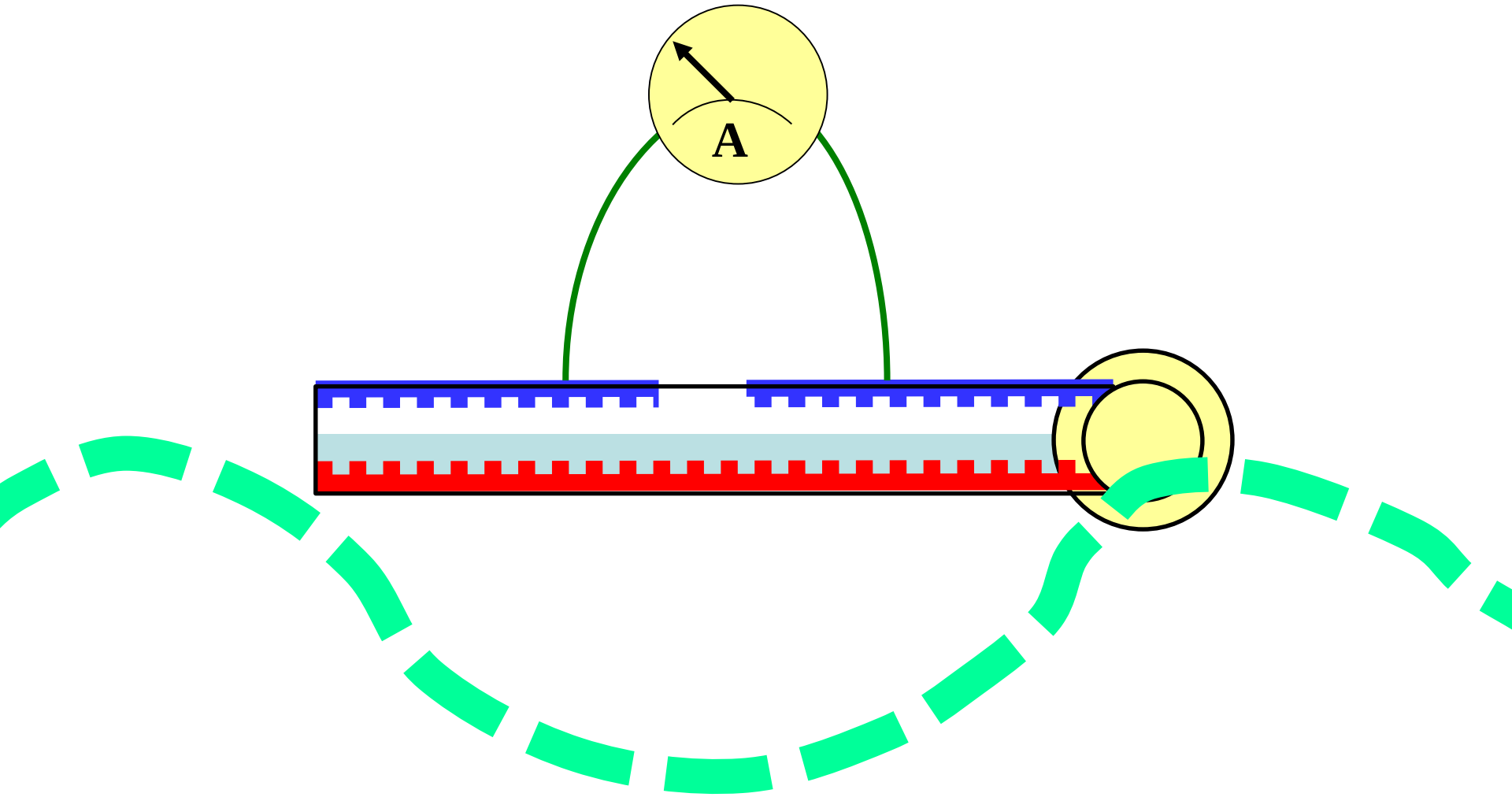
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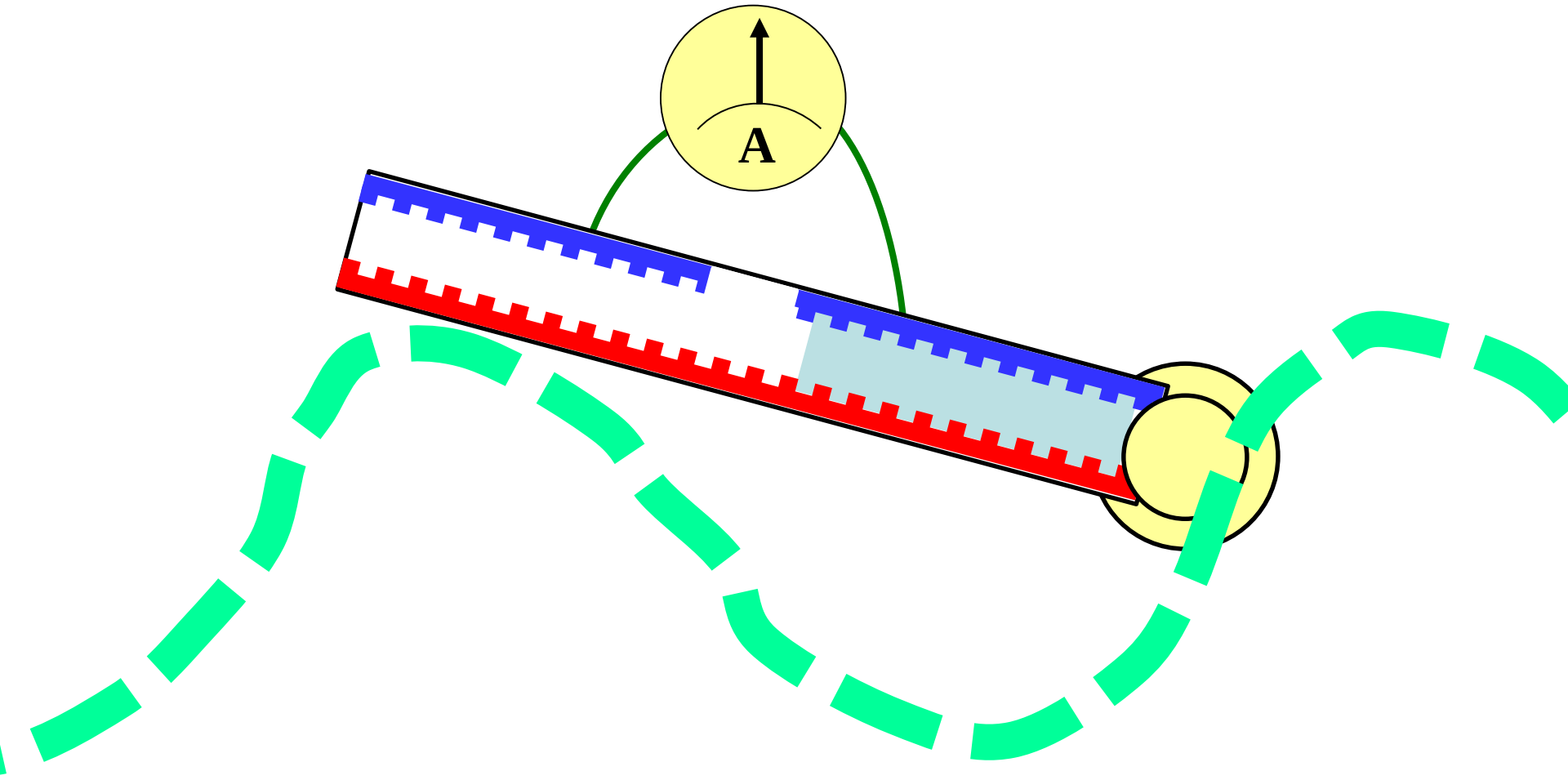
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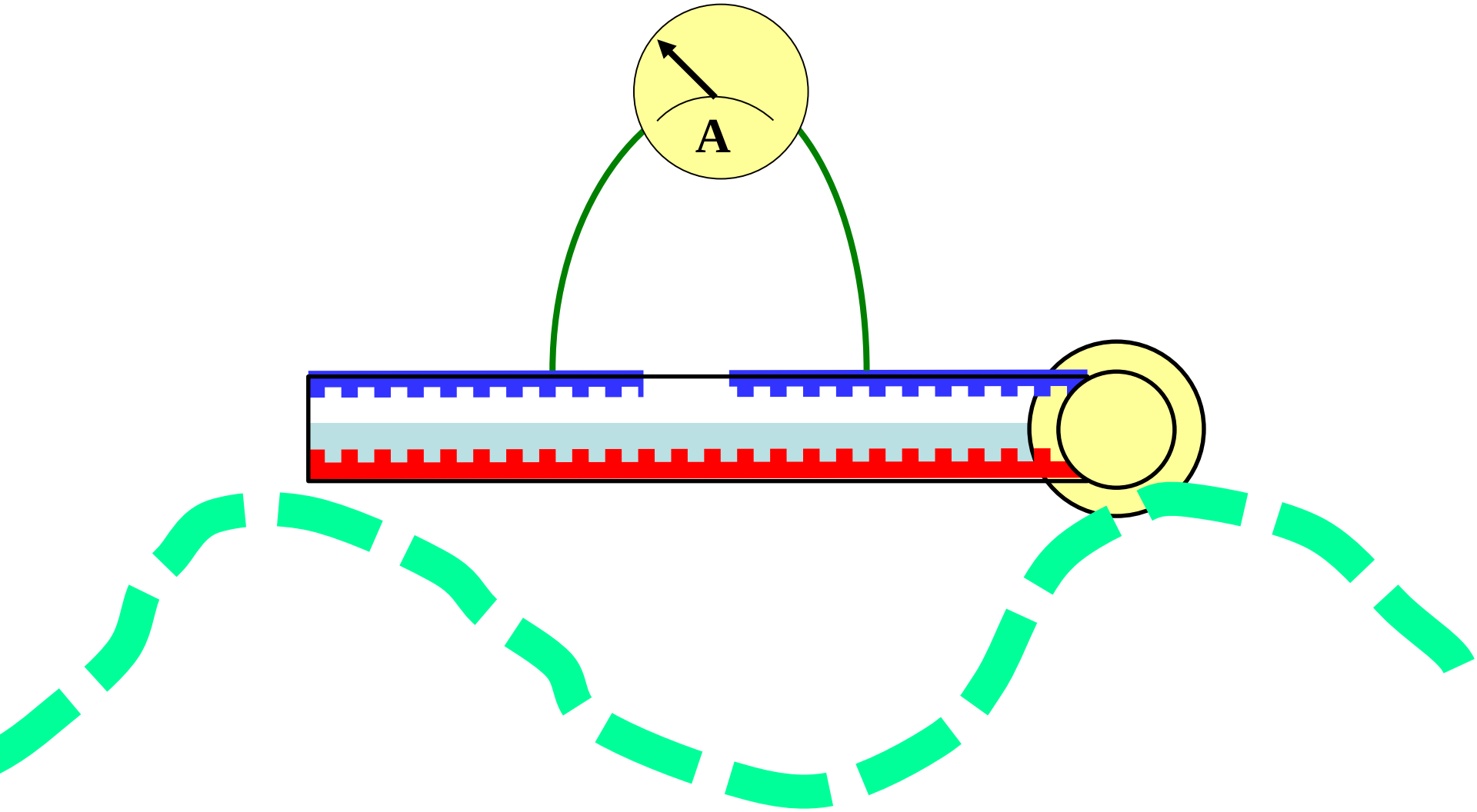
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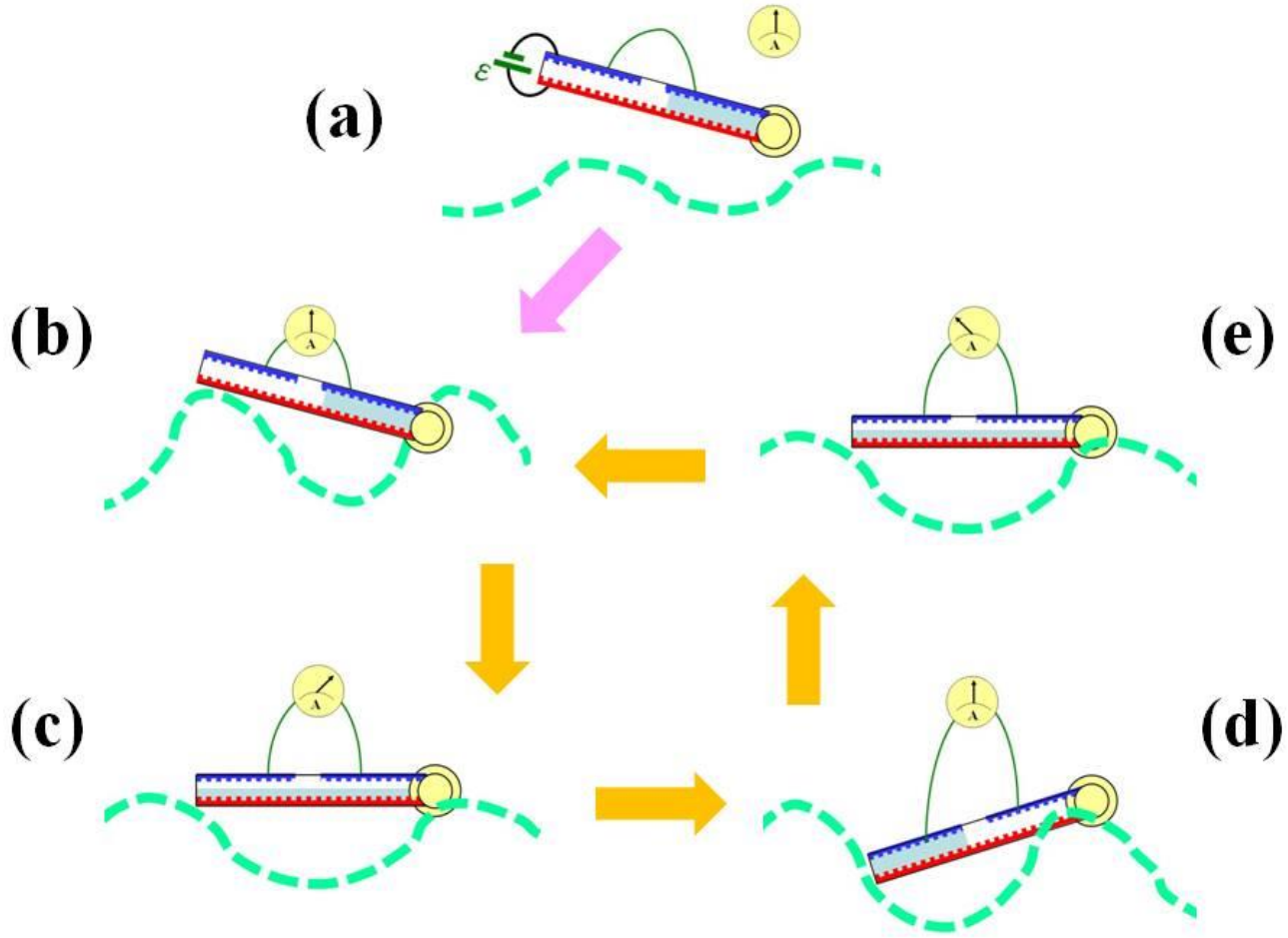

圖三、「雙電容式交流發電機」的其中一款設計之示意圖。

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Reverse electrowetting as a new approach to high-power energy harvesting

Tom Krupenkin[1,2,*] & J. Ashley Taylor[1,2,*]

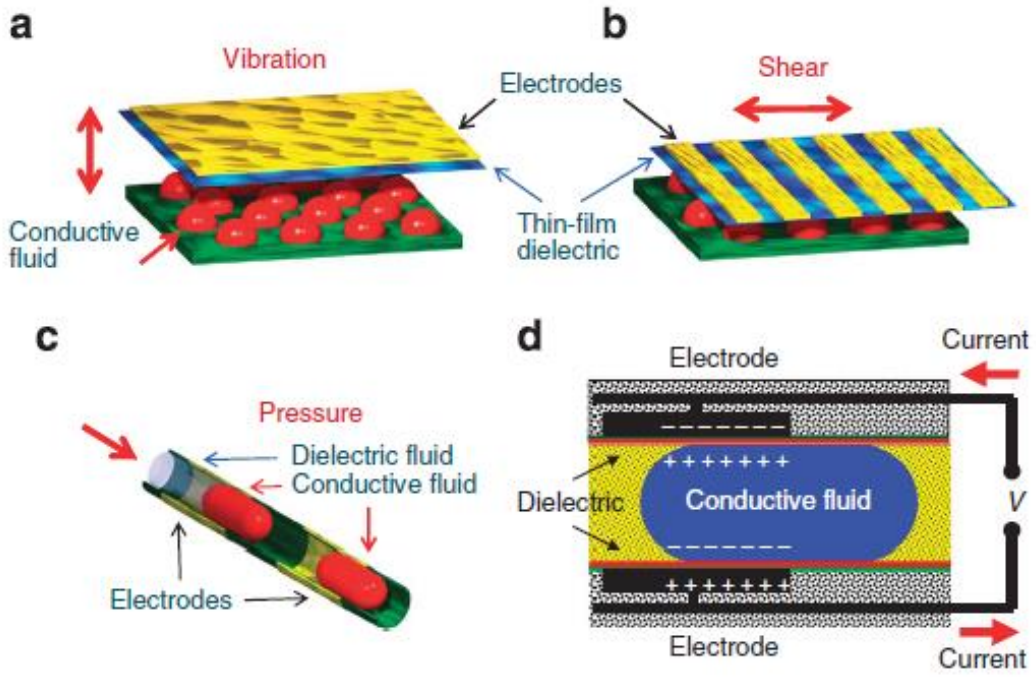

Figure 1 | Schematics of three major droplet actuation mechanisms. These include (**a**) droplets between oscillating plates, (**b**) droplets between sliding plates, and (**c**) droplets in a microchannel. (**d**) Shows in greater detail schematics of reverse-electrowetting-based energy generation process in a microchannel geometry.

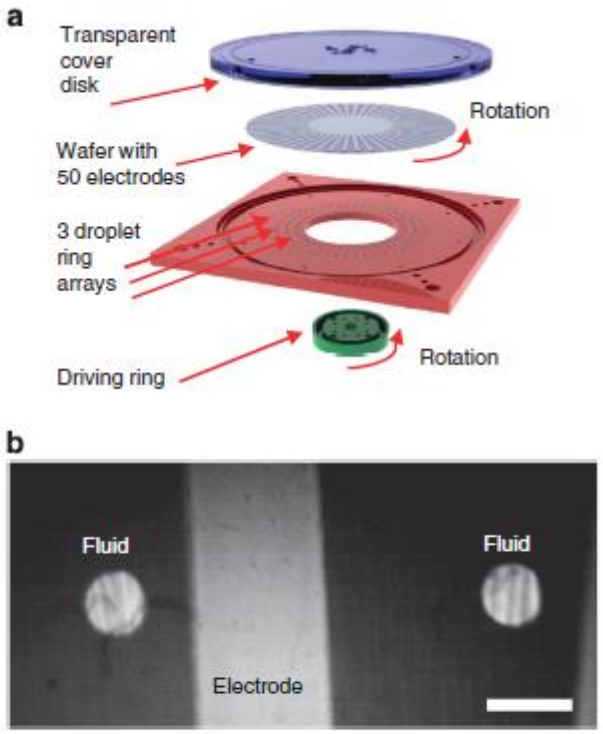

Figure 6 | Experimental set-up for droplets between sliding plates. (**a**) Schematics of the device and (**b**) a frame from a high-speed video showing a top view of the droplets overlapping one of the electrodes. Scale bar represents 1 mm.

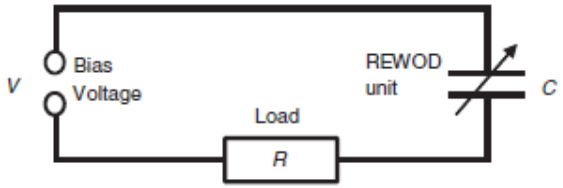

Figure 8 | Schematics of the electric circuit. The circuit used to investigate energy generation includes a source of a bias voltage *V*, a resistive load *R*, and a variable capacitor *C* (the REWOD unit, which represents a harvester set-up, that is, a set of droplets in contact with the electrode grid). The voltage drop on the resistive load was captured by the data acquisition board and converted into electrical current allowing direct calculation of the generated power as a function of time. Resistive loads with the values of *R* in the range from 10^4 to 10^6 Ω were investigated. A battery (with internal resistance of about 1Ω) was used to provide a bias voltage.

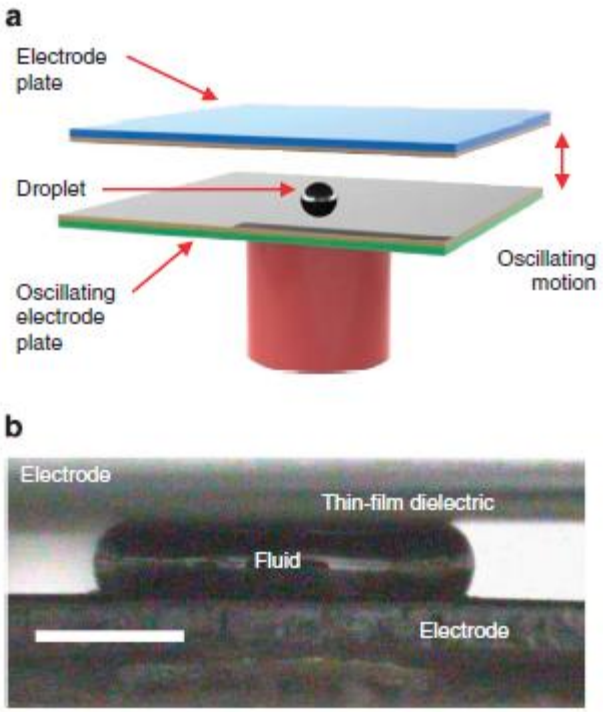

Figure 7 | Experimental set-up for a single droplet between oscillating plates. (**a**) Schematics of the device and (**b**) a frame from a high-speed video showing a side view of a droplet squeezed between two electrodes. Scale bar represents 0.5 mm.

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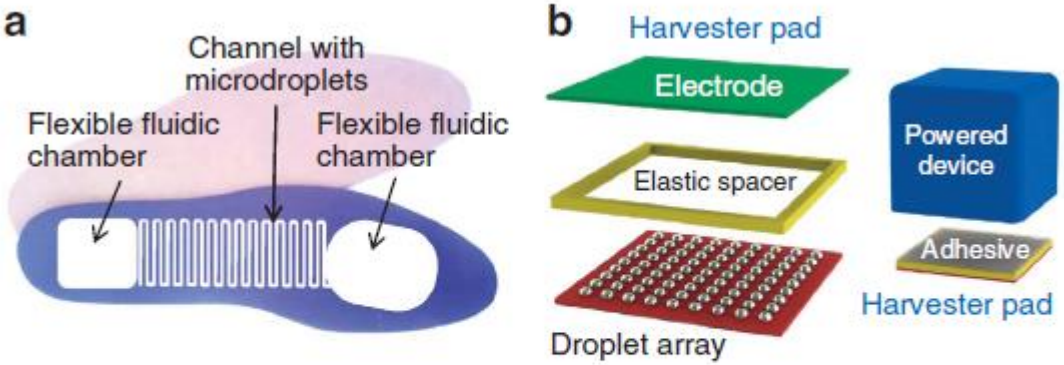

Figure 4 | Schematics of two REWOD applications. (**a**) Footwear-
ınd (**b**) a REWOD-based

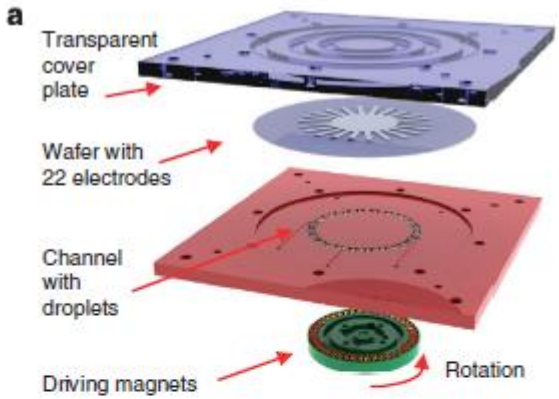

Figure 5 | Experimental set-up for droplets in a microchannel. (**a**) Schematics of the device and (**b**) a frame from a high-speed video showing a top view of the droplets overlapping one of the electrodes. Scale bar represents 1 mm.

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Electrical power generation by mechanically modulating electrical double layers

Jong Kyun Moon[1], Jaeki Jeong[1], Dongyun Lee[1] & Hyuk Kyu Pak[1]

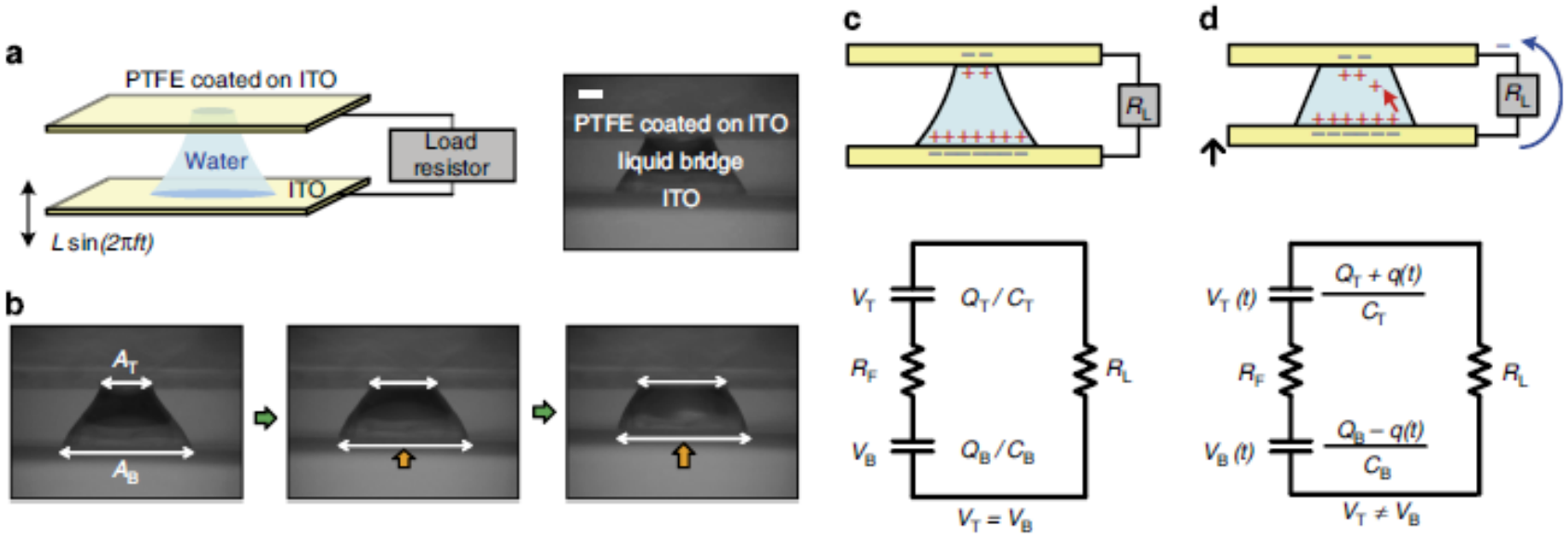


Figure 1 | Schematic diagram of the experiment and resistor-capacitor circuit model. (**a**) Experimental setup and (**b**) video images of water bridge over time. Scale bar, 1 mm. Charge distributions on EDLCs and corresponding equivalent electrical circuits (**c**) when the water bridge height is fixed in time (equilibrium state) and (**d**) at the very moment when the two plates are approaching each other (non-equilibrium state). Within a couple of periods after the vibration starts, the system reaches a steady state.

Jong Kyun Moon, *et. al.*, Nature Communications 2485 (2013)

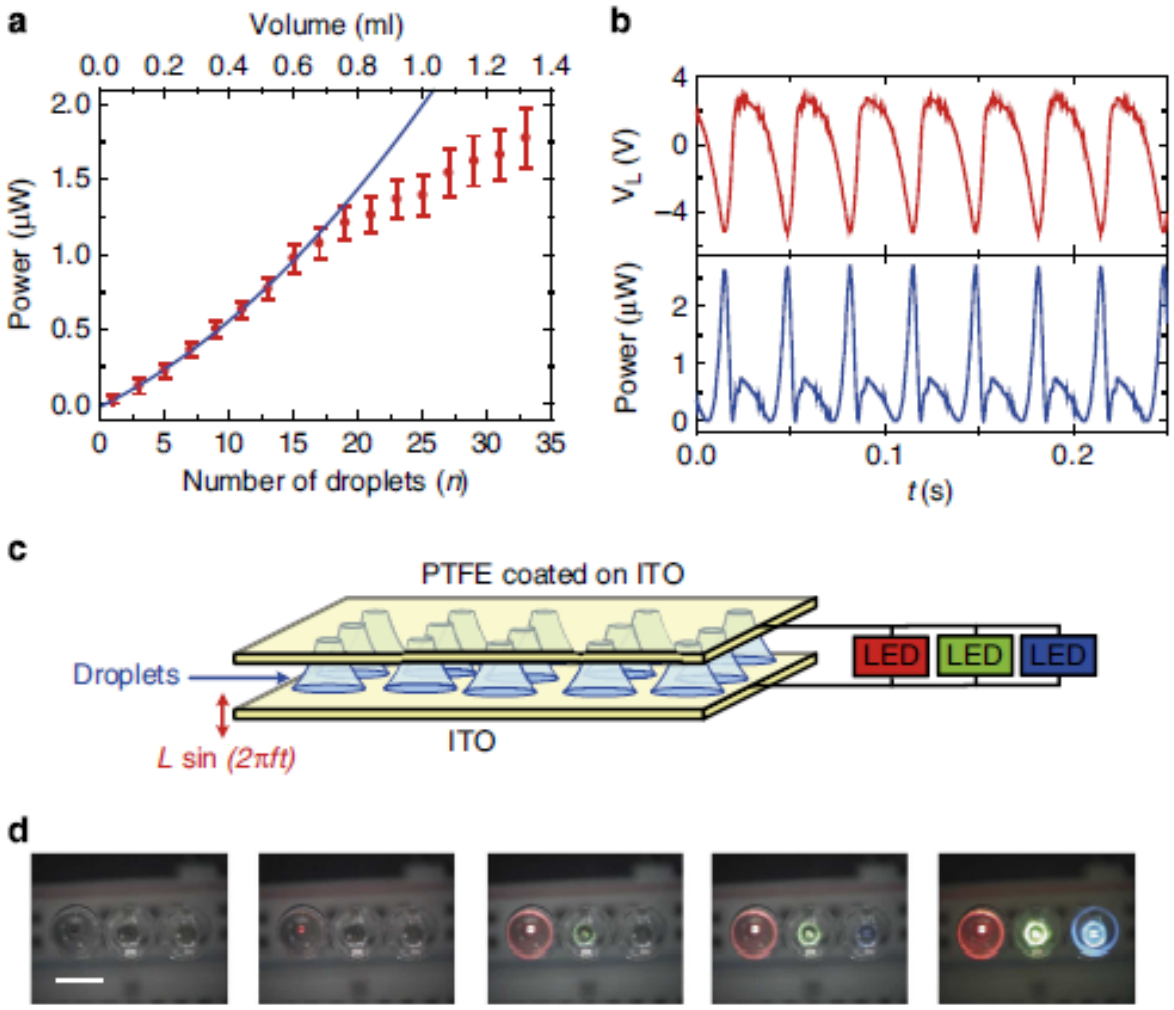


Figure 4 | Micro-watt power generation. (**a**) Power versus number of bridges for a sinusoidal input with $f = 30$ Hz, $L = 0.6$ mm and $R_L = 10$ MΩ (solid dots). Solid curve represents a parabolic fit. Volume of each single droplet is 40 μl. Data show mean ± s.d. (**b**) Voltage drop V_L and instantaneous power with time for the case of a 14 droplet system with the same conditions as (**a**). (**c**) Experimental setup for enhanced power generation. Three different LEDs are connected in parallel. (**d**) LEDs are lit up using 24 bridges for a sinusoidal input with $f = 30$ Hz. Total volume of droplets is about 1 ml. Scale bar, 5 mm. The threshold voltage of the red, green, and blue LED is 1.8, 3 and 3.2 V, respectively.

另類綠能科技的研發

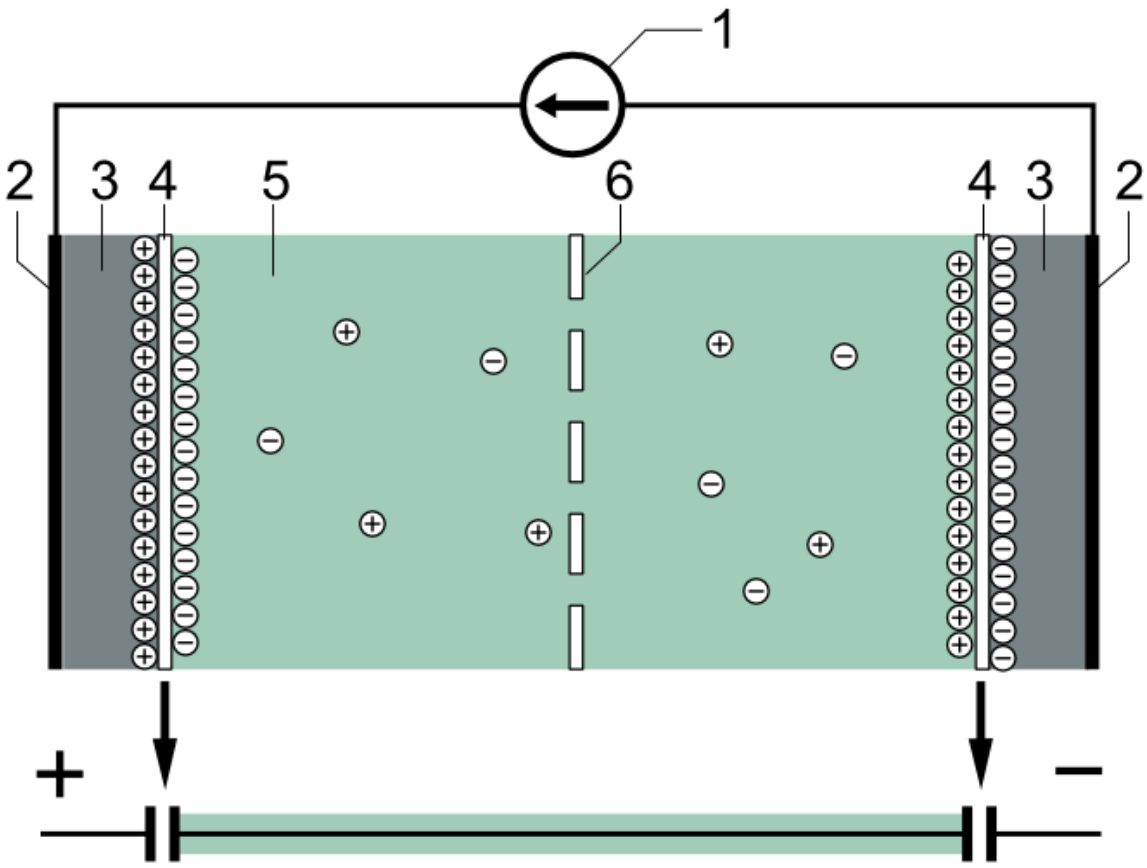
(1) 新型的(超級)電容器 ➔ 有效的電能儲存裝置

(2) 非電磁感應式的發電機制 ➔ 有效汲取各種再生能源

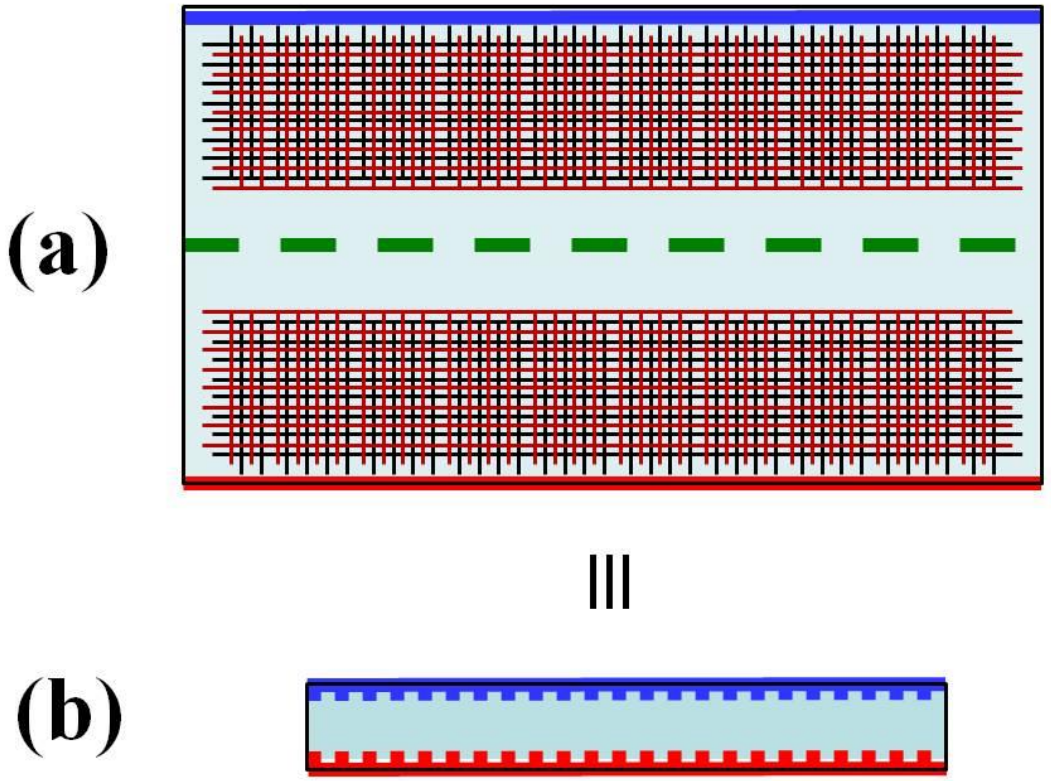
(3) 箔式(非典型)的平價光電池 ➔ 普及太陽能的接收利用

(4) 表面張力仲介的光能汲取裝置 ➔ 開發新型的太陽能利用

http://en.wikipedia.org/wiki/Supercapacitor



Principle construction of a supercapacitor; 1. power source, 2. collector, 3.polarized electrode, 4. Helmholtz double layer, 5. electrolyte having positive and negative ions, 6. Separator.

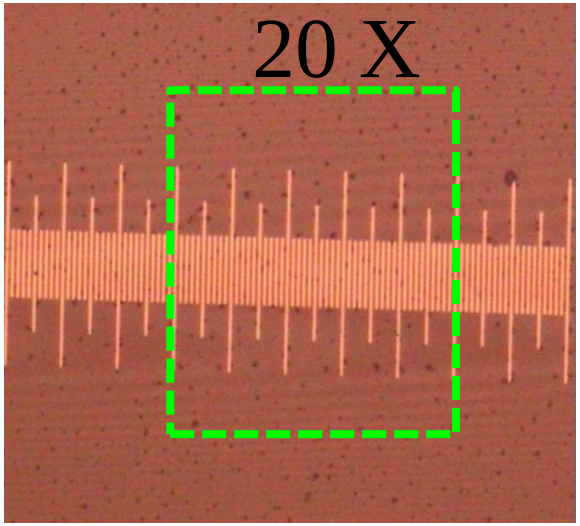


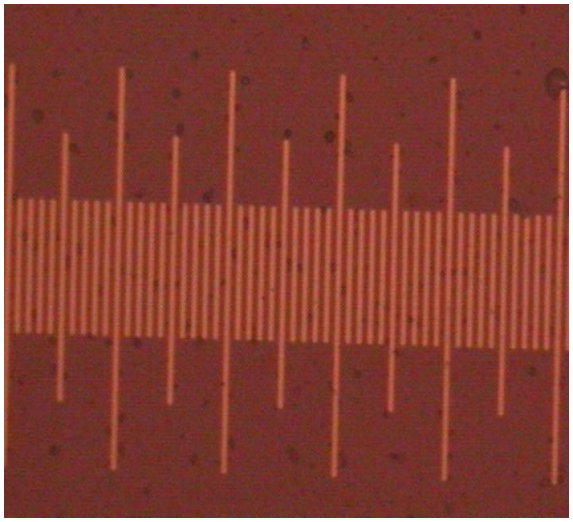
圖一、我們所設計的電容器之示意圖。
(a) 利用一張金屬細網來摺捲成單一的電極，應 可兼具良好的導電性、極大化的有效表面積，以及可讓電解液川流其間所需的結構穩固性。根據超級電容的基本架構，電容器中充滿了電解液，並以濾膜將兩個電極隔開，以防互相接觸。
(b) 代表本款電容器的縮圖，將會用於圖三示意「雙電容式交流發電機」的運作原理。

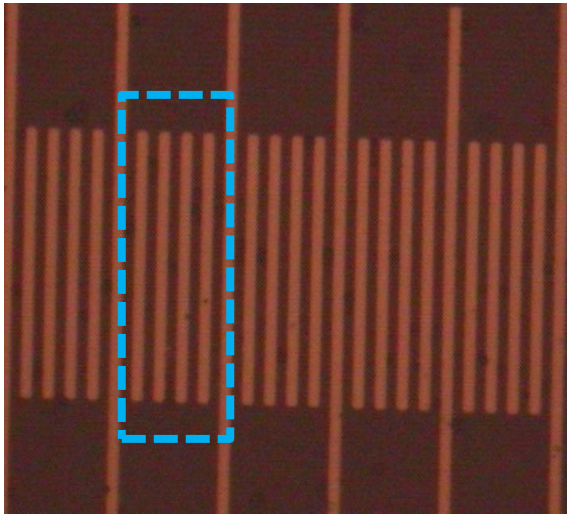
5 X

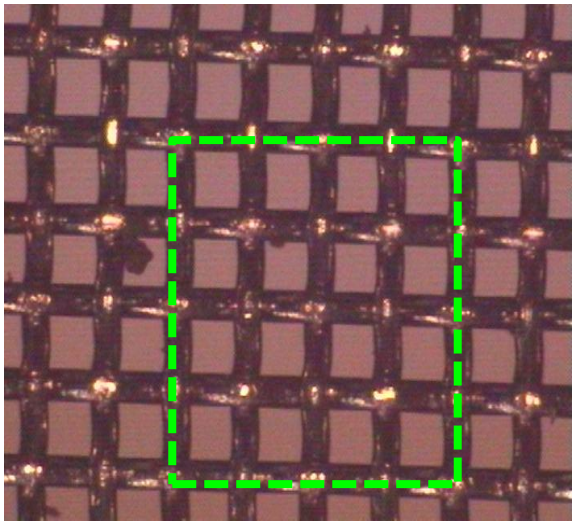
10 X

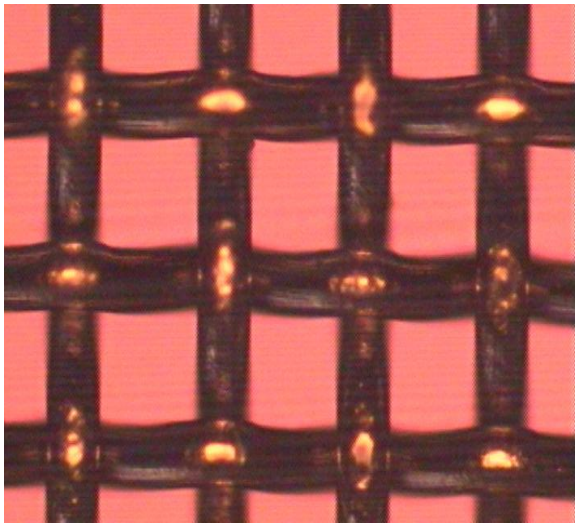
20 X

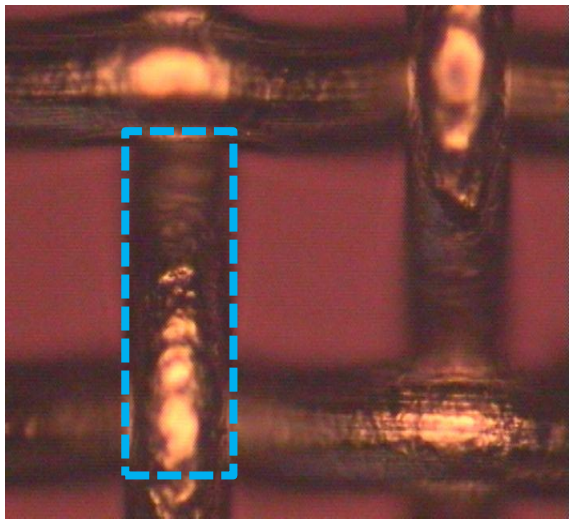


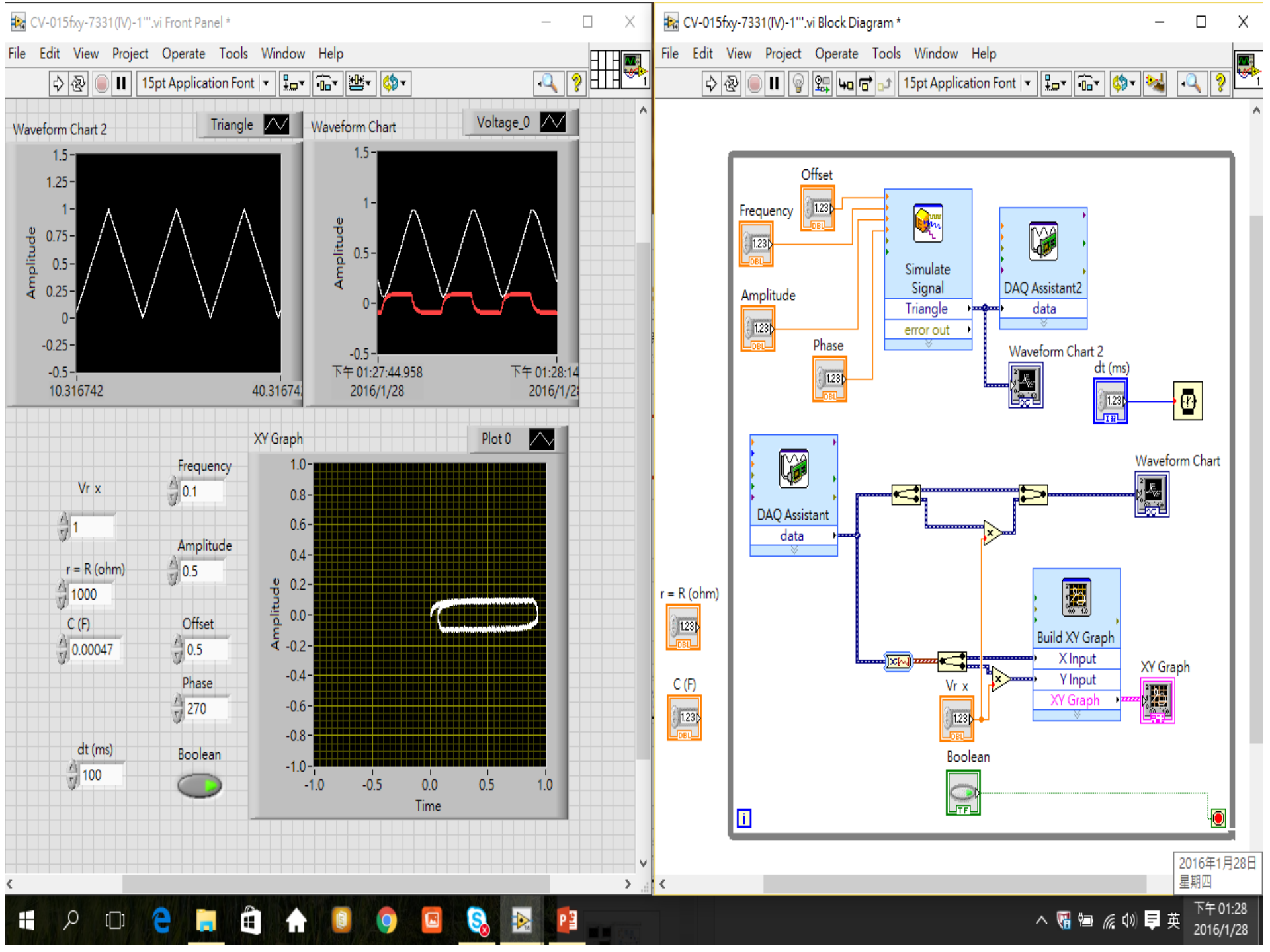











CV-015fxy-7331(IV)-1'''.vi Front Panel *
File Edit View Project Operate Tools Window Help
15pt Application Font
Waveform Chart 2
Triangle
Amplitude
10.316742
40.31674
Waveform Chart
Voltage_0
下午 01:27:44.958
2016/1/28
下午 01:28:14
2016/1/2
XY Graph
Plot 0
Time
Vr x
1
r = R (ohm)
1000
C (F)
0.00047
Frequency
0.1
Amplitude
0.5
Offset
0.5
Phase
270
dt (ms)
100
Boolean
CV-015fxy-7331(IV)-1'''.vi Block Diagram *
File Edit View Project Operate Tools Window Help
15pt Application Font
Offset
Frequency
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Phase
Simulate Signal
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error out
DAQ Assistant2
data
Waveform Chart 2
dt (ms)
DAQ Assistant
data
Waveform Chart
r = R (ohm)
C (F)
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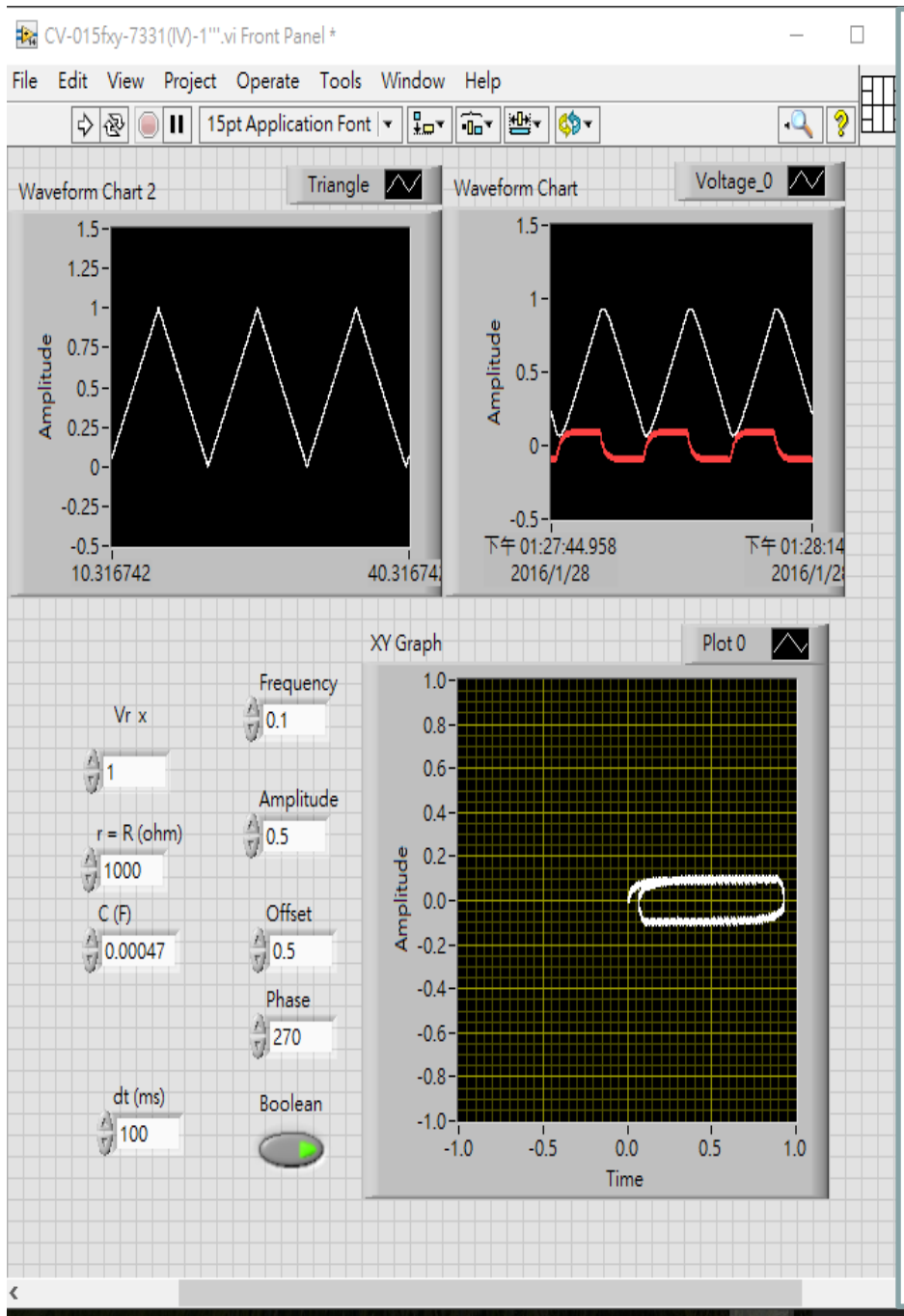
Build XY Graph
X Input
Y Input
XY Graph
XY Graph
Boolean
2016年1月28日
星期四
下午 01:28
2016/1/28



2016-01-28 (四)

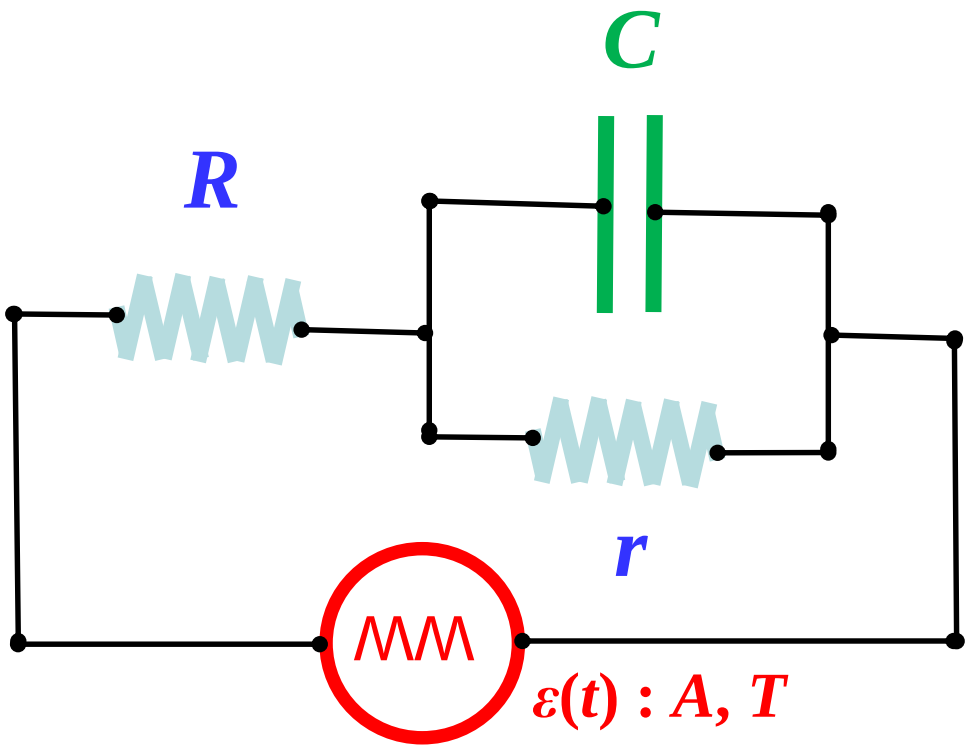
T = 10 sec

V = 0 ~ +1 V

R = 1000 Ω

$V_r x \equiv Vr / (I \cdot R) = 1$

C = 470 μF (已知)



$dq/dt = i_C(t)$

$i_R(t) = i_C(t) + i_r(t)$

$q(t)/C = V_C = i_r(t) \cdot r$

$\varepsilon(t) = i_R(t) \cdot R + i_r(t) \cdot r$

$$di_r/dt = [\varepsilon(t) - i_r(t) \cdot (R + r)] / C\,R\,r$$

C = 0.1F

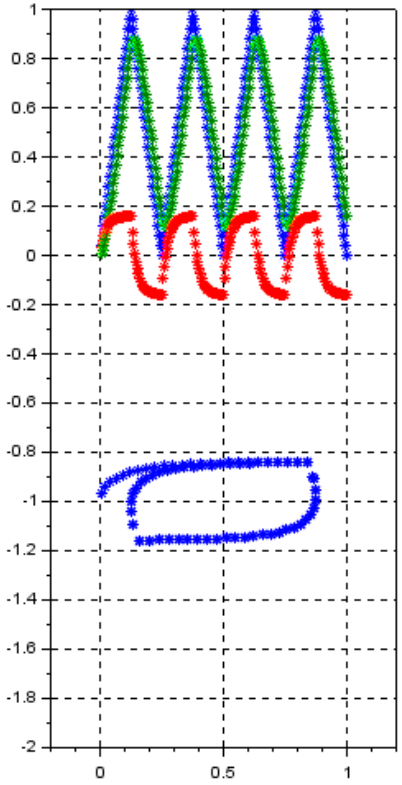
C = 1F

C = 10F

r = 1 MΩ

r = 1 KΩ

r = 1 Ω



R = 100 Ω

R = 10 Ω

R = 1 Ω

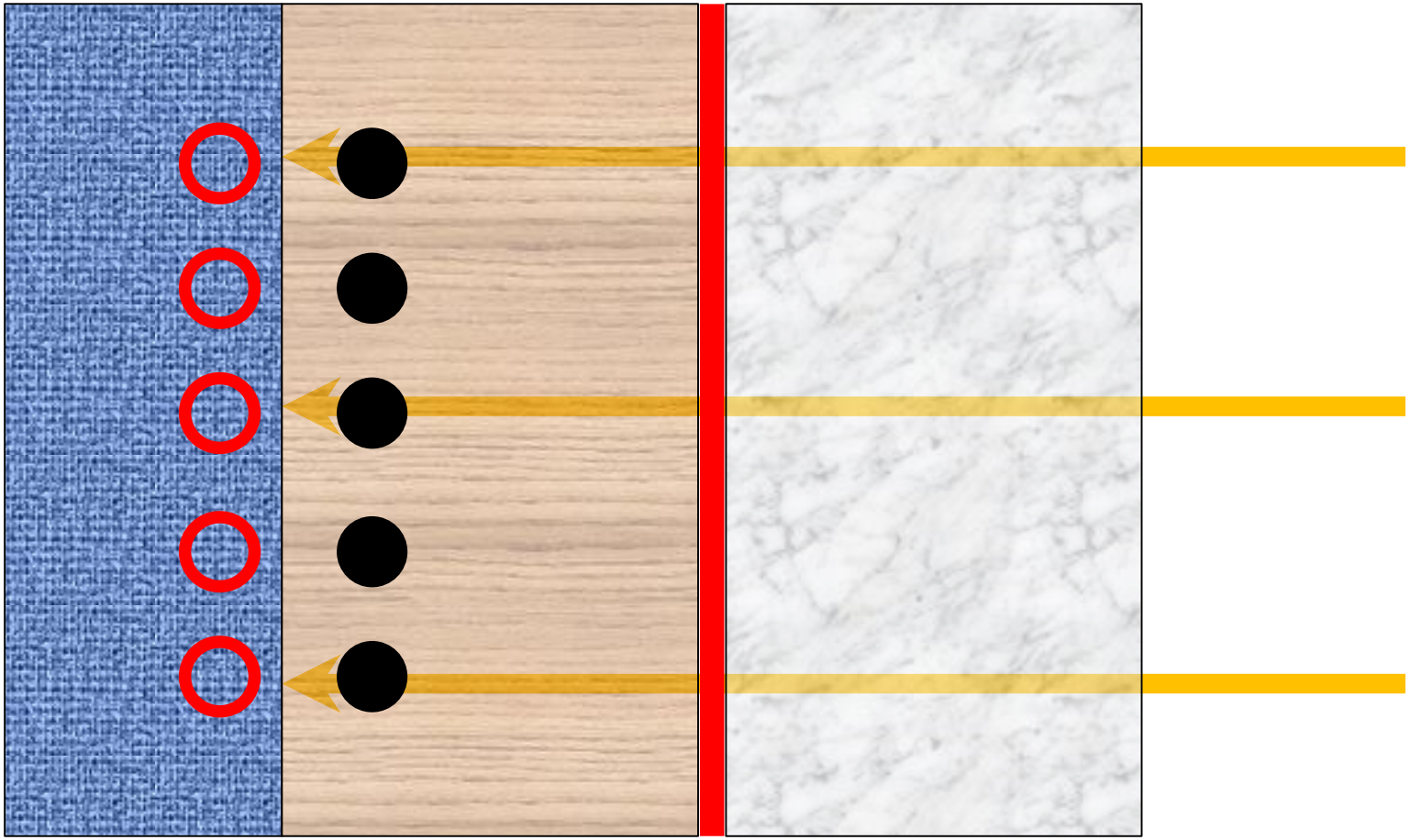
另類綠能科技的研發

(1) 新型的(超級)電容器 ➔ 有效的電能儲存裝置

(2) 非電磁感應式的發電機制 ➔ 有效汲取各種再生能源

(3) 箔式(非典型)的平價光電池 ➔ 普及太陽能的接收利用

(4) 表面張力仲介的光能汲取裝置 ➔ 開發新型的太陽能利用



二、另類綠能科技的研發

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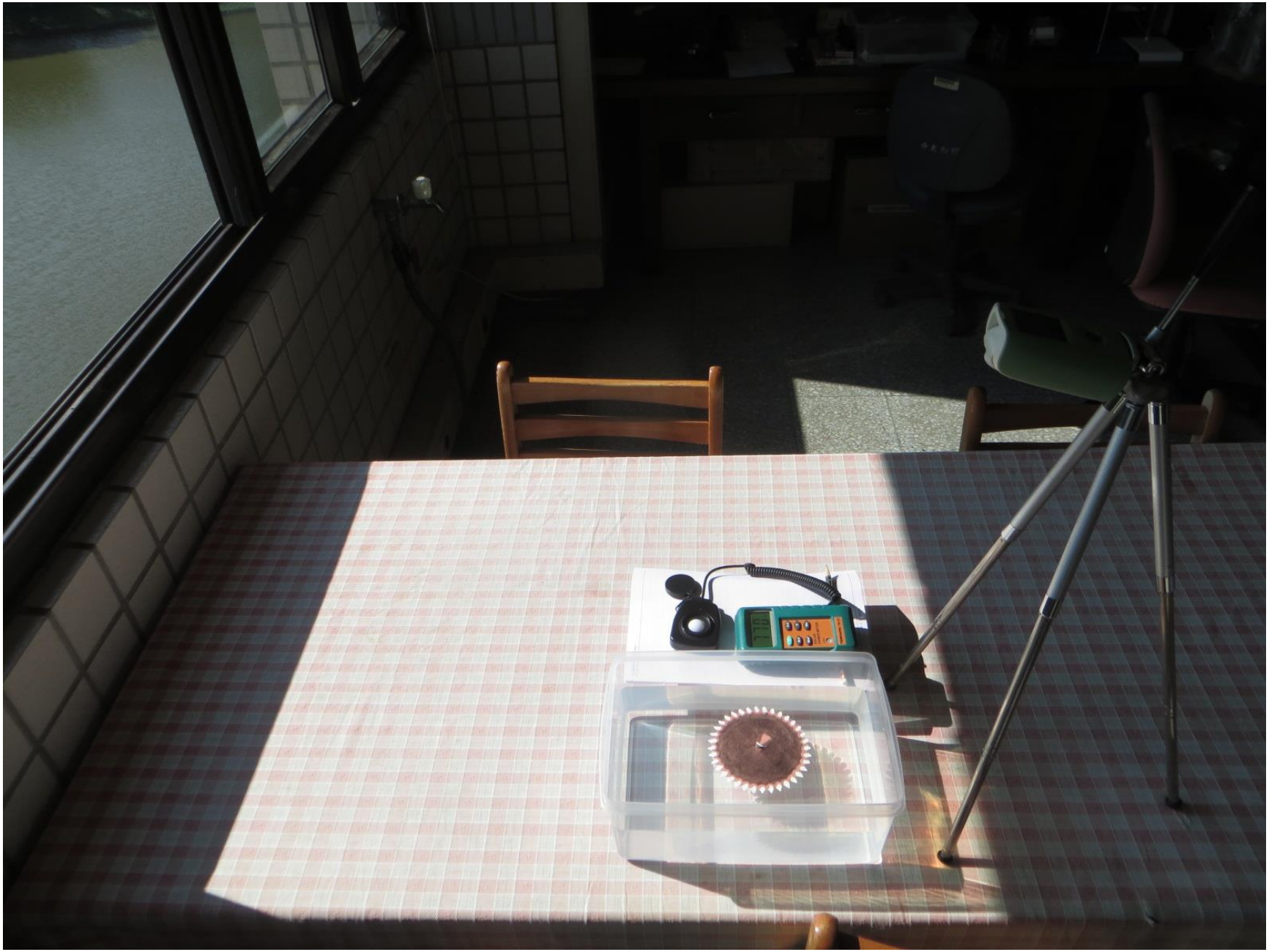
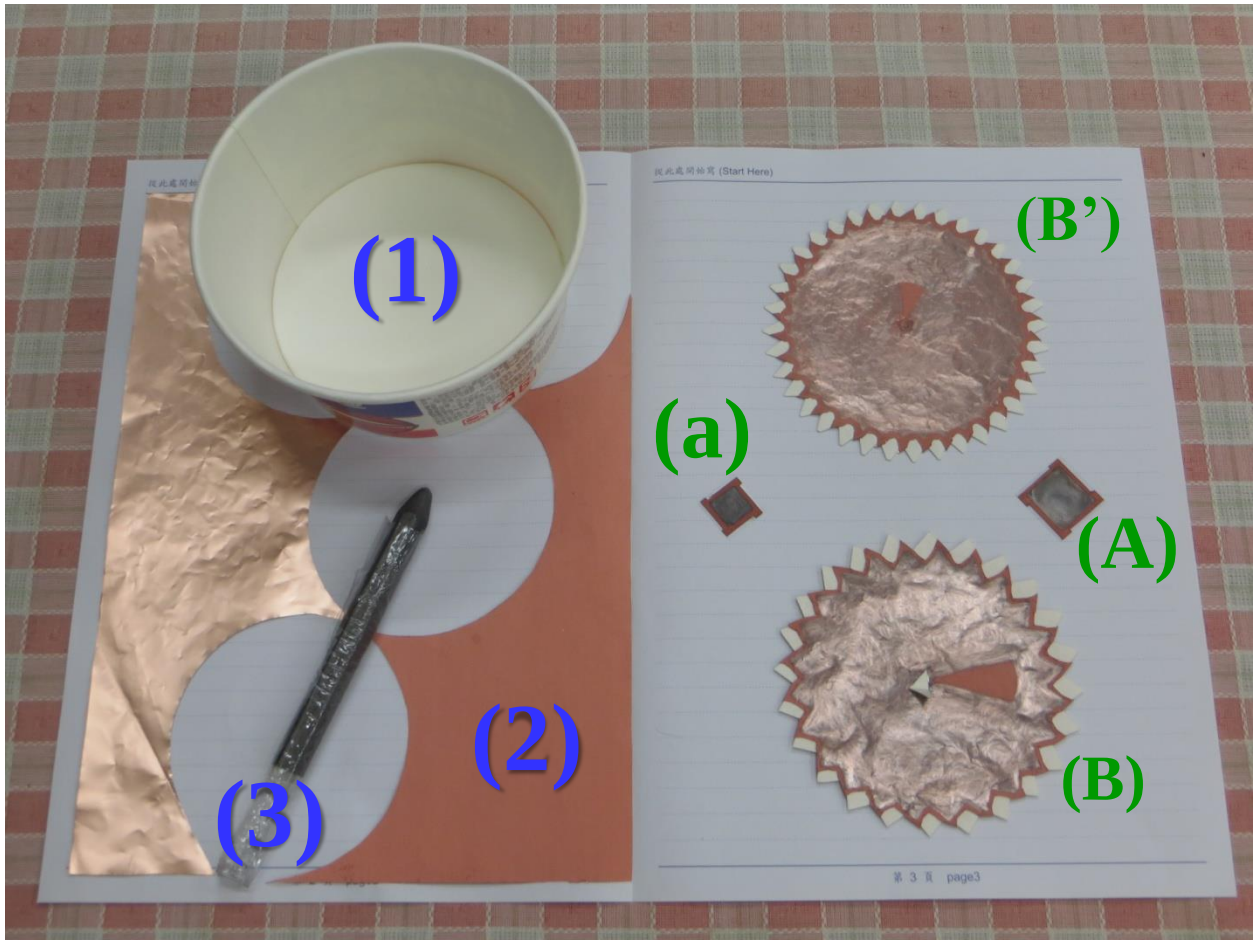




(1’) + (2) + (3) = (a) or (A) < NT$ 10

(1) + (2) + (3) = (B) or (B’) < NT$ 50

(1) Card board

d ~ 11 cm

(1’) Cover glass

18 mm & 24 mm

(2) Copper foil

thickness ~ 35 μm

(3) 9B pencil

(a) Small square

18 mm X 18 mm

(A) Large square

24 mm X 24 mm

(B) 24-teeth rotor

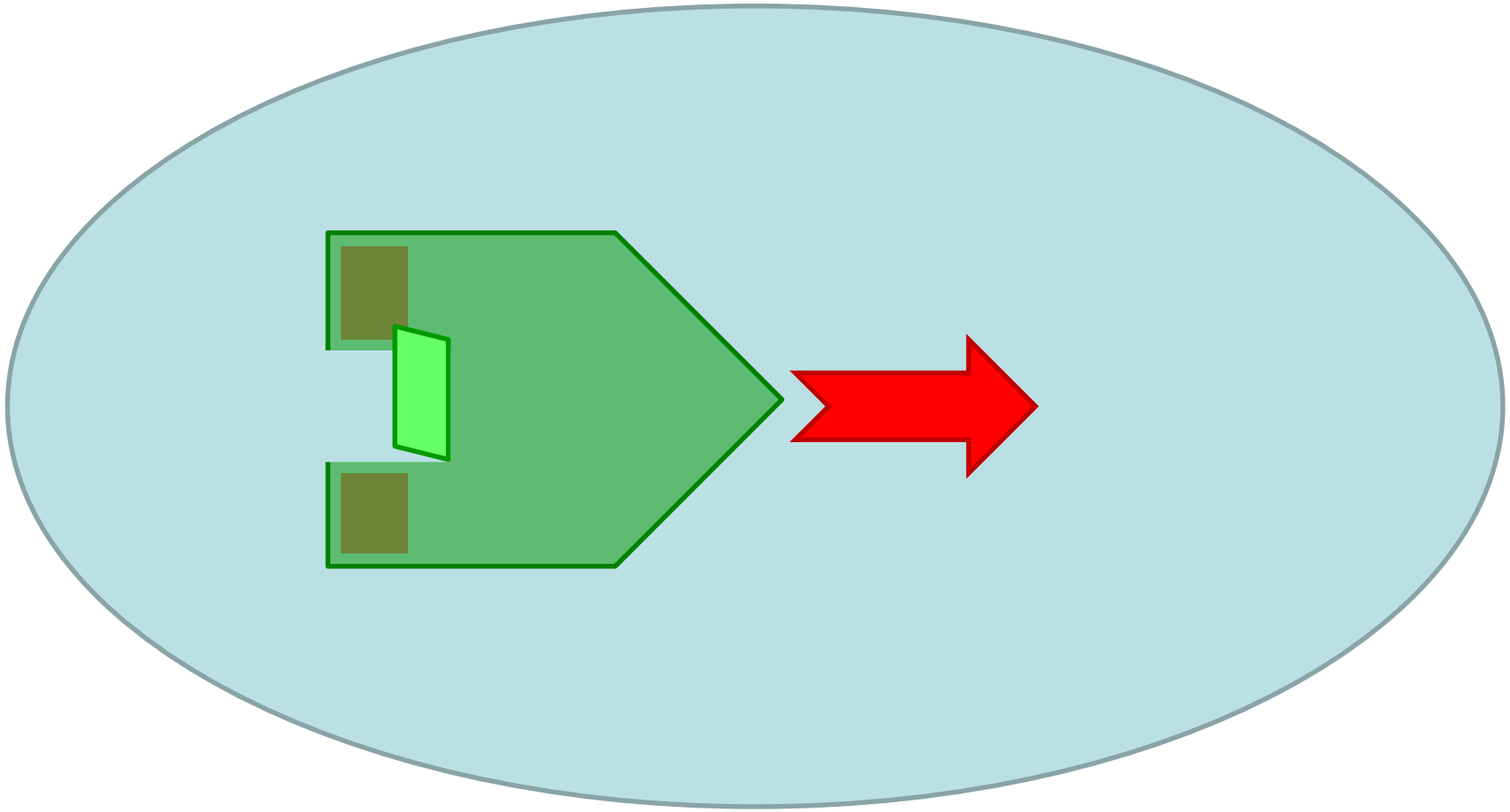
d ~ 11 cm

(B’) 36-teeth rotor

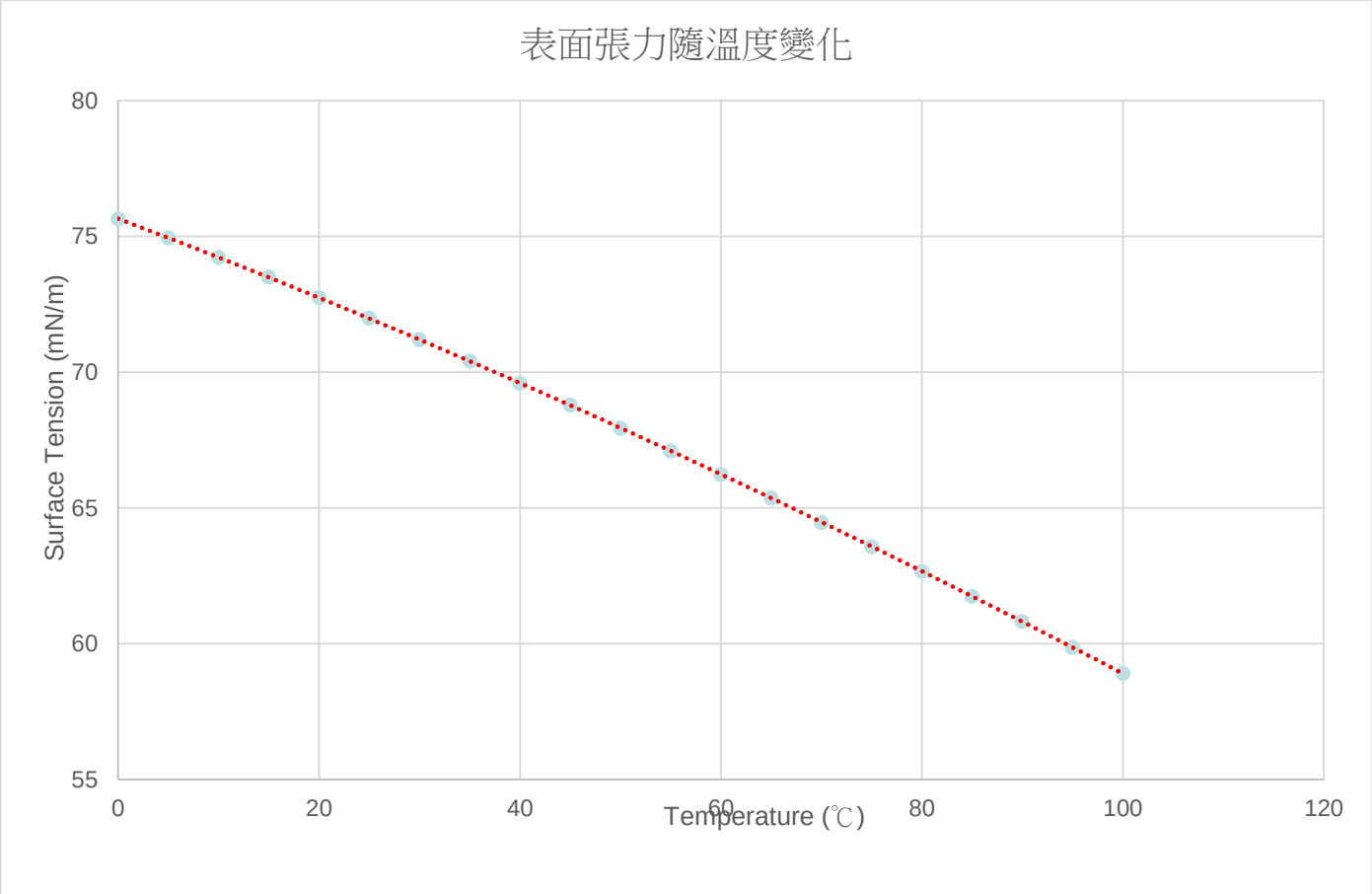
d ~ 11 cm

I. What is new under the sun?

Once upon the time : Soap boats

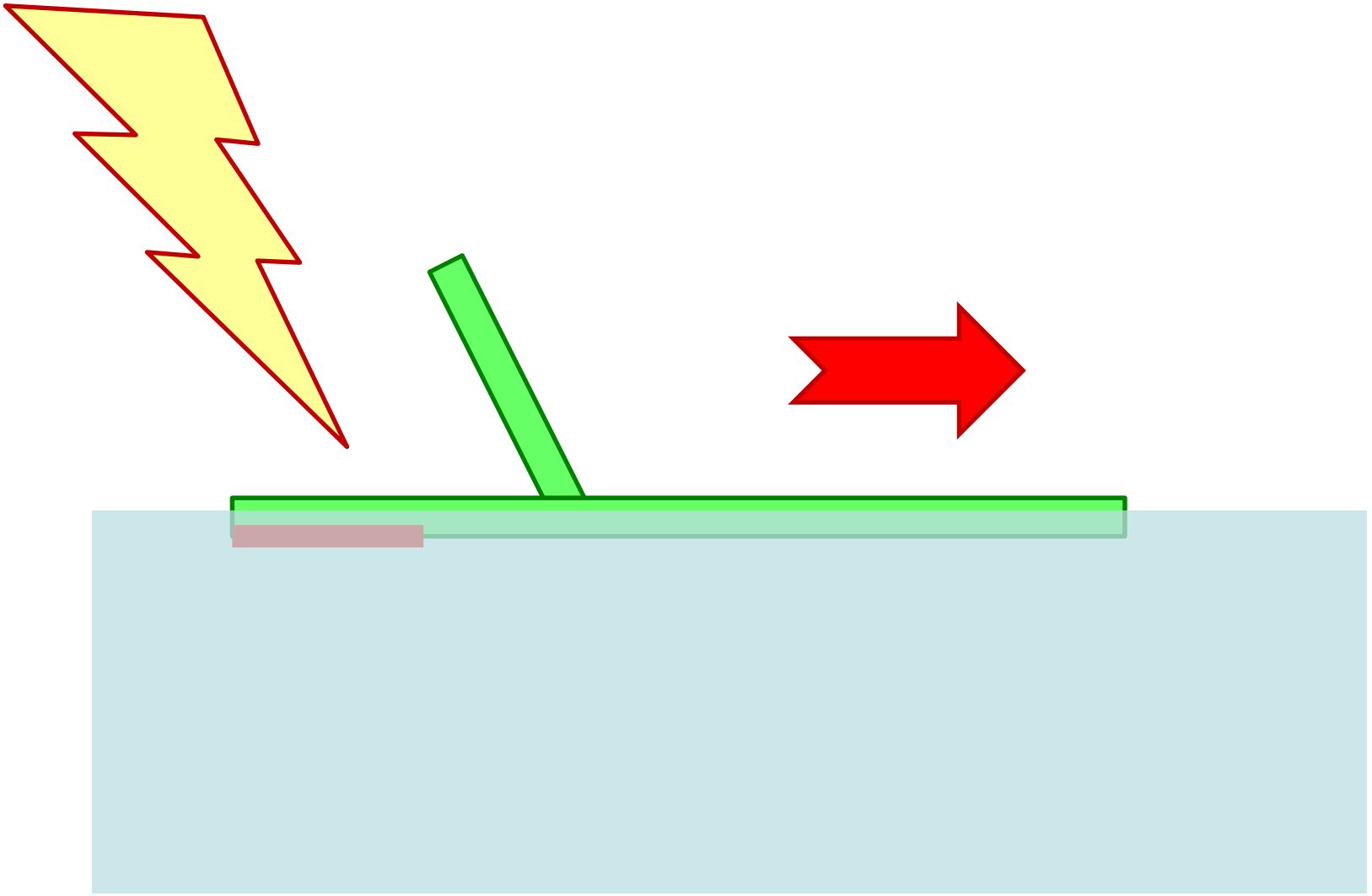


Surface tension of water as a function of temperature

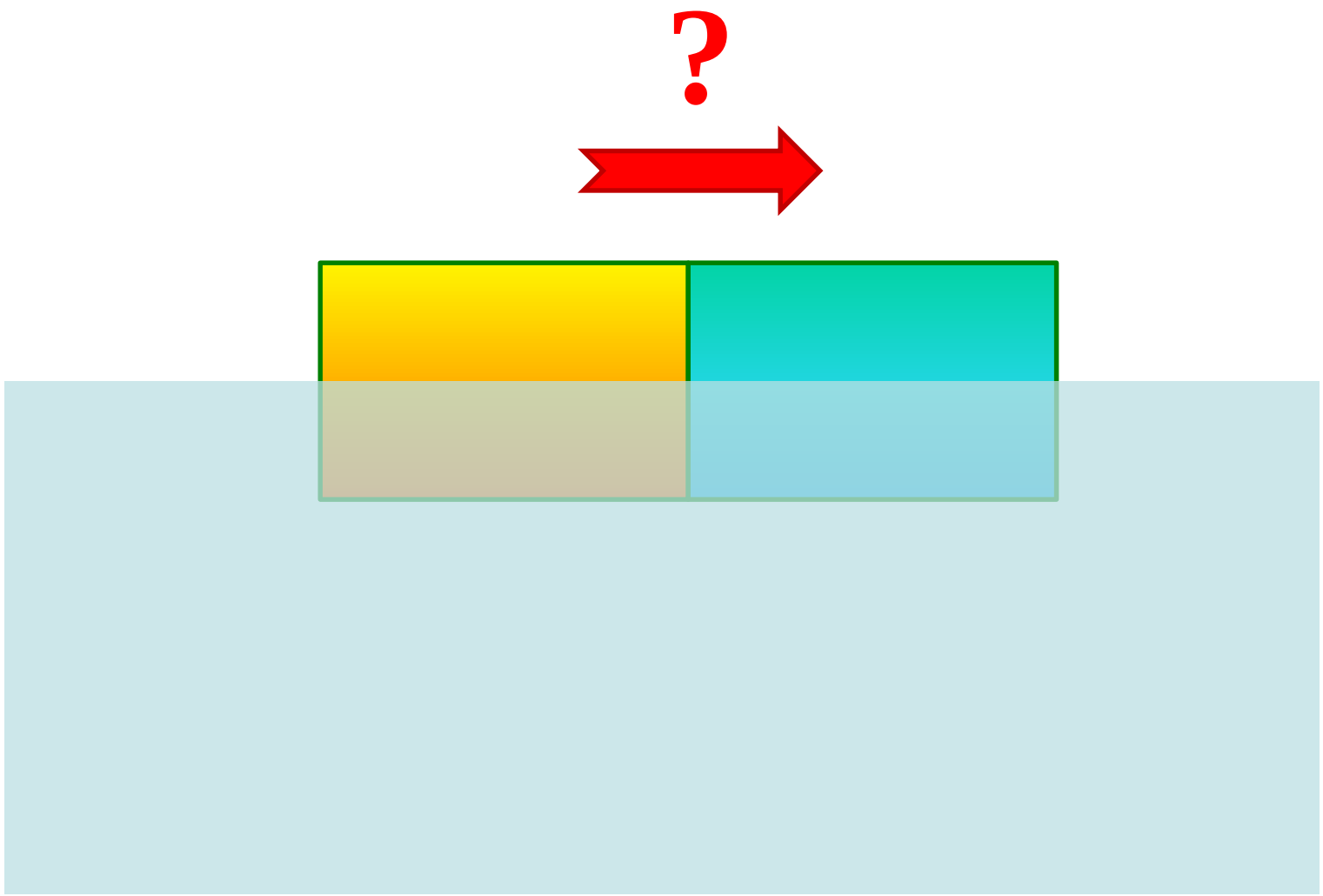


W. V. Kayser, J. Colloid Interface Sci., Vol. 56, Issue 3, September 1976, 622-627.

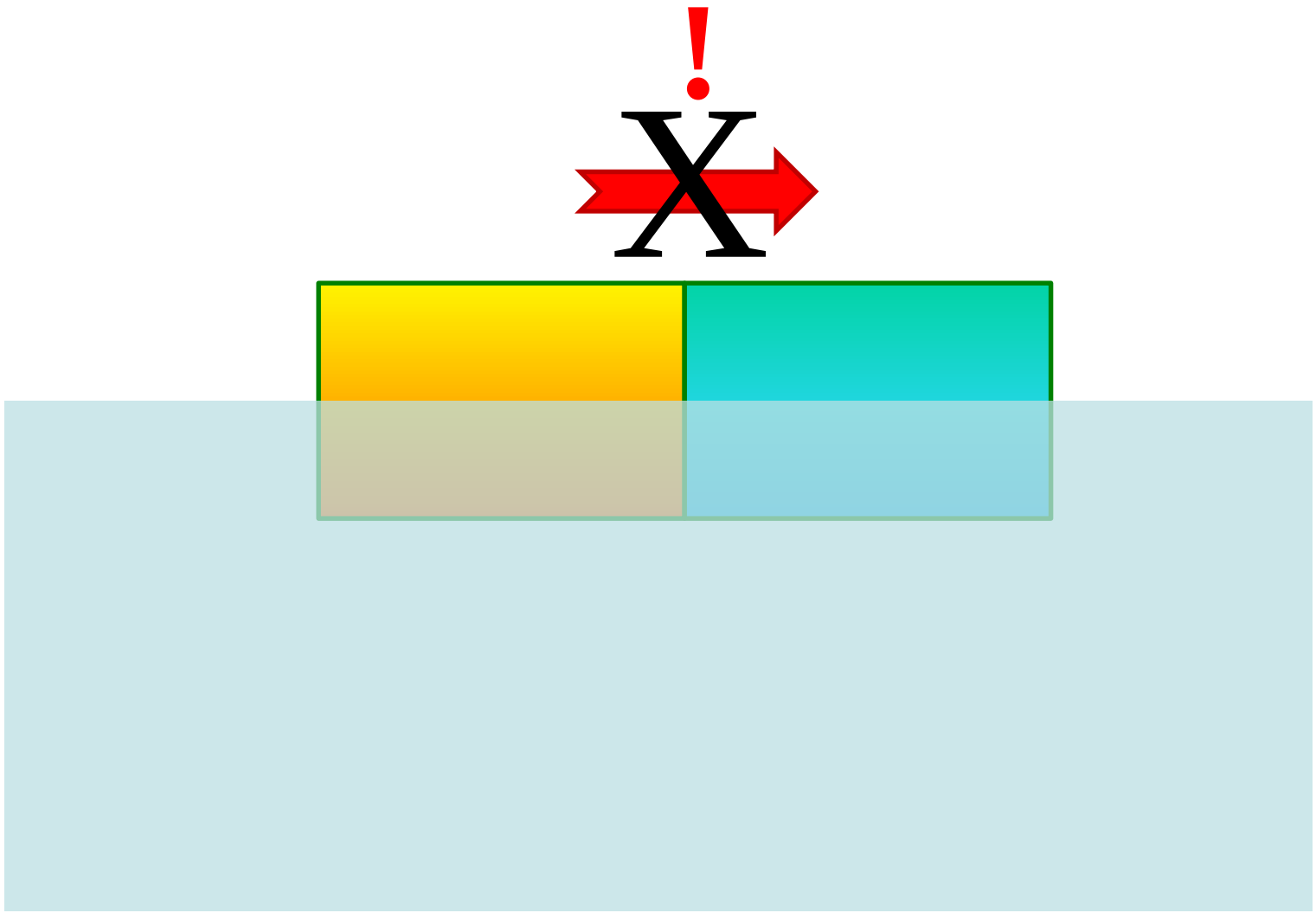
A few years ago : How about heating?



A big mistake : twin Coke cans



A big mistake : twin Coke cans



J|A|C|S COMMUNICATIONS

Published on Web 03/27/2009

Surface Tension Mediated Conversion of Light to Work

David Okawa,[†,‡] Stefan J. Pastine,[†] Alex Zettl,[‡,§] and Jean M. J. Fréchet*[,†,§]

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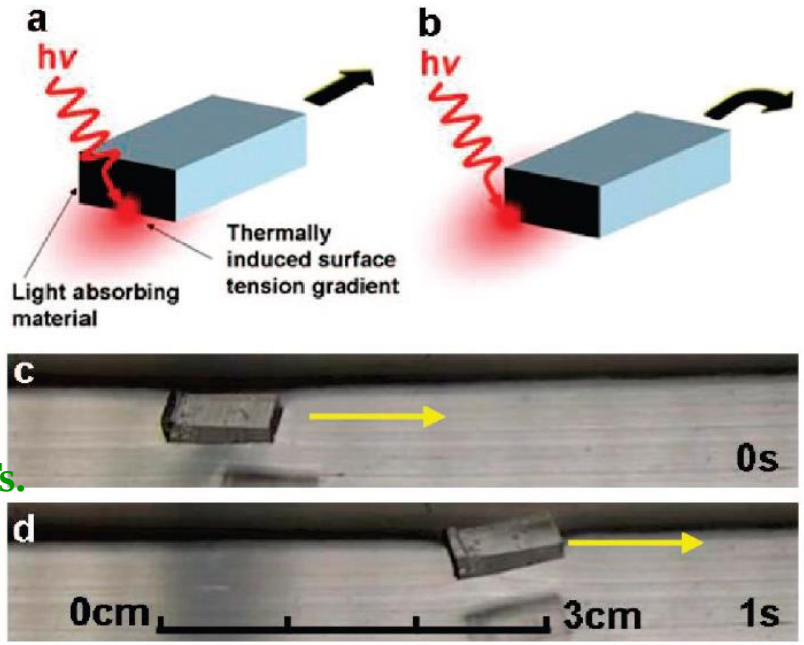
Received January 7, 2009; E-mail: frechet@berkeley.edu

Ⓦ This paper contains enhanced objects available on the Internet at http://pubs.acs.org/jacs.

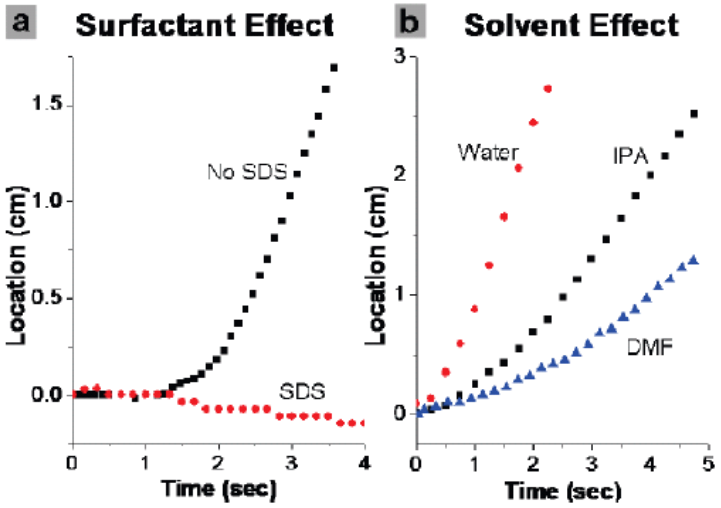
* **VANTs (vertically aligned carbon nanotube forests**

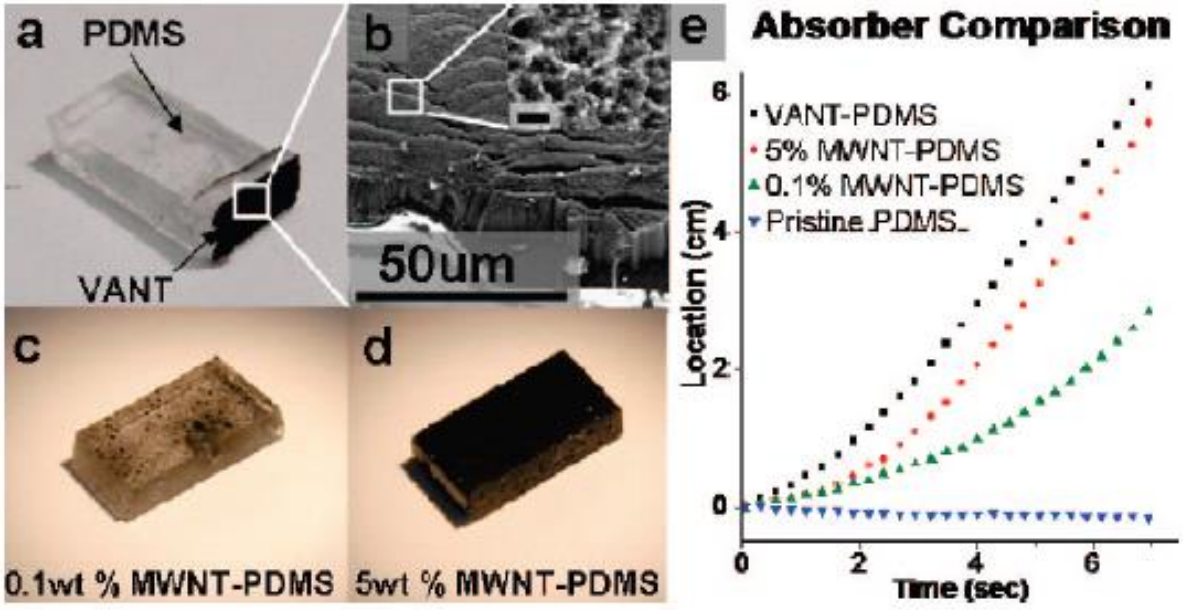
* **PDMS (polydimethylsiloxane)**
  (i) optically transparent;
  (ii) a density similar to water;
  (iii) strong adhesion to VANTs;
  (iv) elasticity while maintaining nanoscale roughness and macroscopic structure of VANTs.

* **Focused sunlight or a near-infrared laser (450 mW, 785 nm Diode Laser)**



David Okawa, et.al., J. Am. Chem. Soc. 131 (2009) pp.5396-5398





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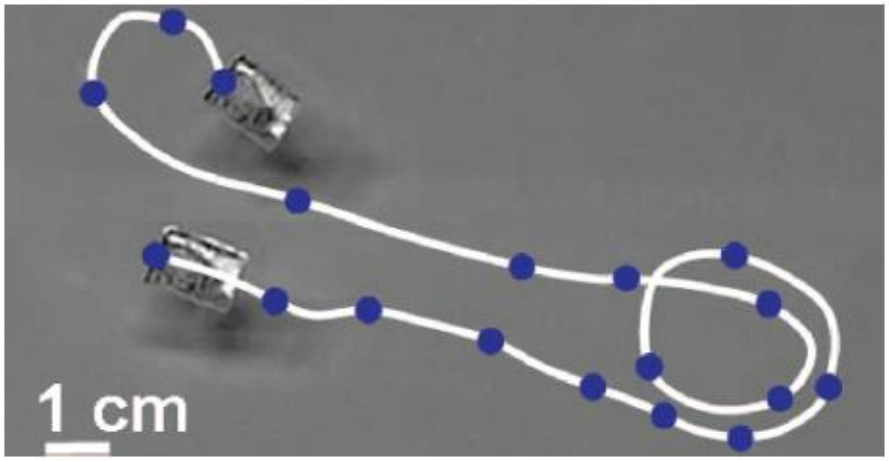
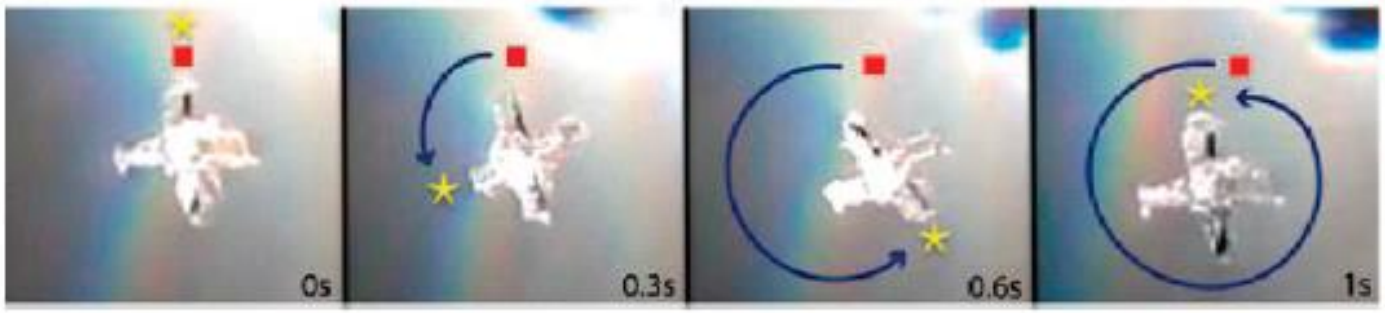


* **Directionally controlled linear motion**

* **Built-in directionality**

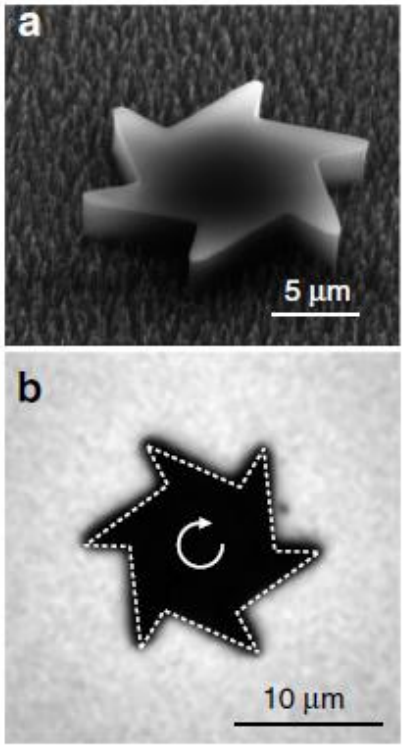


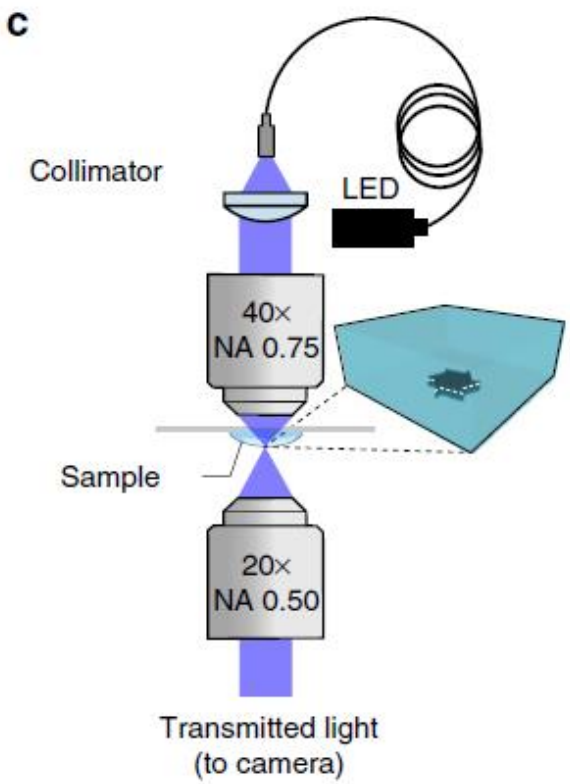
David Okawa, et.al., J. Am. Chem. Soc. 131 (2009) pp.5396-5398

Received 20 Mar 2015 | Accepted 18 Jun 2015 | Published 29 Jul 2015 DOI: 10.1038/ncomms8855 OPEN

Micromotors with asymmetric shape that efficiently convert light into work by thermocapillary effects

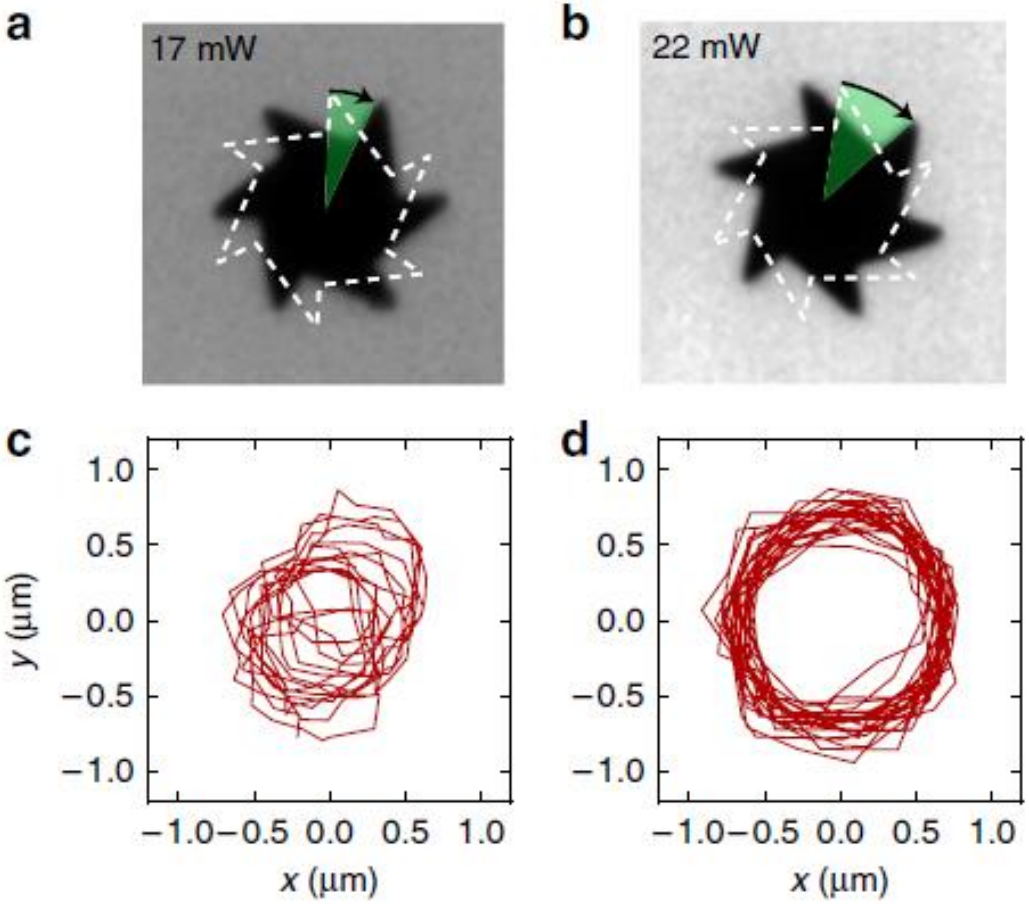
Claudio Maggi[1], Filippo Saglimbeni[1], Michele Dipalo[2], Francesco De Angelis[2] & Roberto Di Leonardo[1,3]

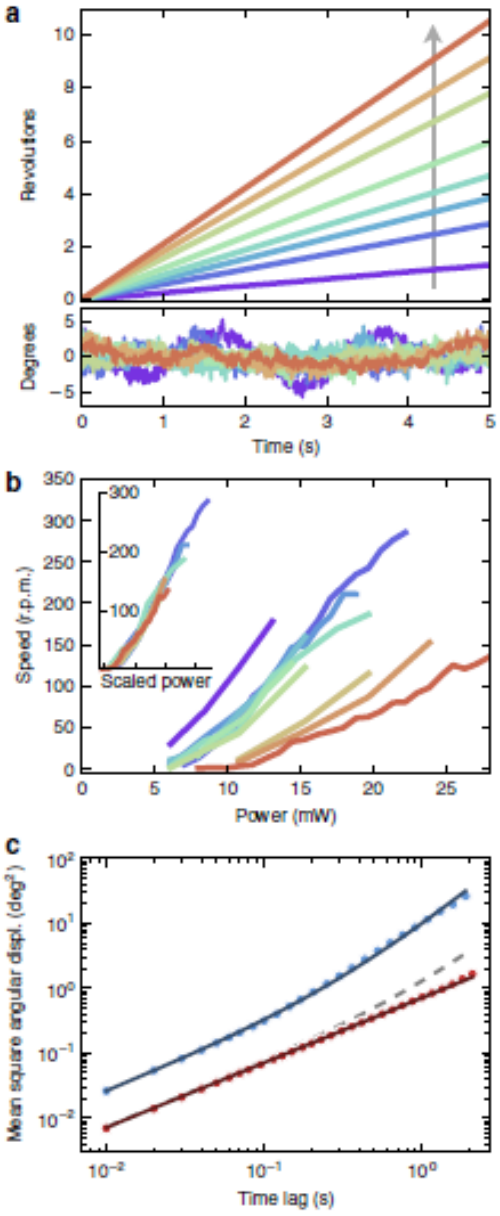




* **Direct conversion of light into work in a contactless, controlable and continuous way.**
* **Asymmetric microgears fabricated by laser lithography**
* **Uniformly coated with a light-absorbing material**
* **Focused high power LED lamp (450 mW, 785 nm Diode Laser)**
* **300 r.p.m.**

Claudio Maggi, et.al., Nature Communications 8855 (2015)



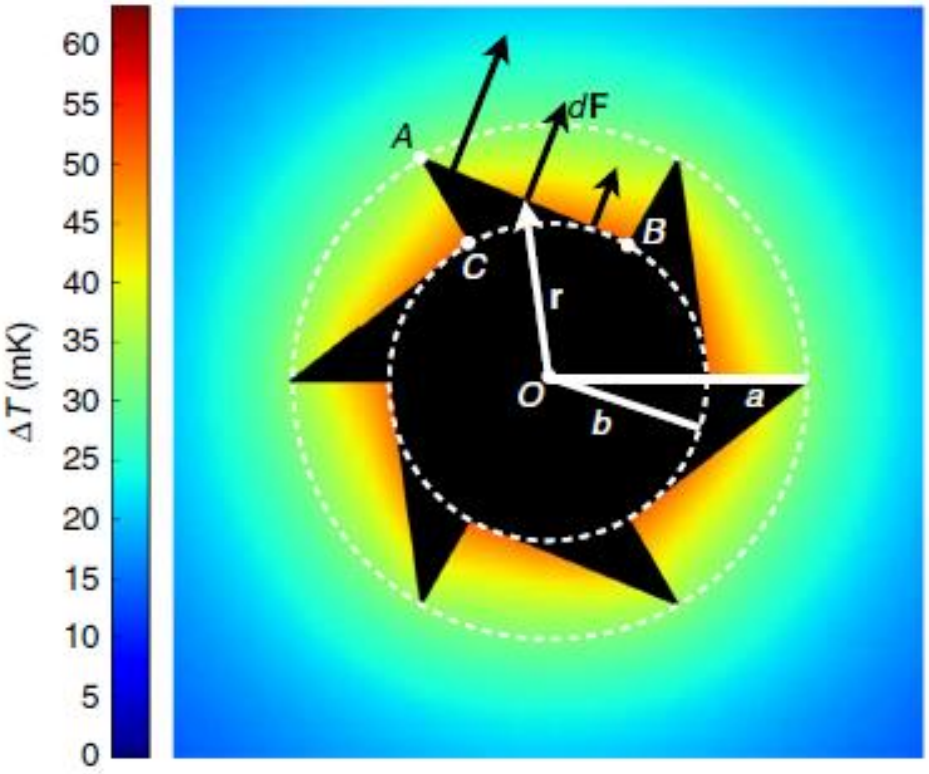


For a rotating Brownian motion: $\langle \Delta\theta^2(t) \rangle = \langle [\theta(t) - \theta(0)]^2 \rangle = 2D_r t + \Omega^2 t^2$

Rotational diffusion coefficient: $D_r = k_B T / \Gamma$

Rotational viscous drag: Γ

Claudio Maggi, et.al., Nature Communications 8855 (2015)



$$\boldsymbol{\tau} = \int \mathbf{r}\times d\mathbf{F} = \int \mathbf{r}\times\hat{n}\,\gamma(T)ds$$

$$\boldsymbol{\tau} = m(\boldsymbol{\tau}_{AB} + \boldsymbol{\tau}_{AC})$$

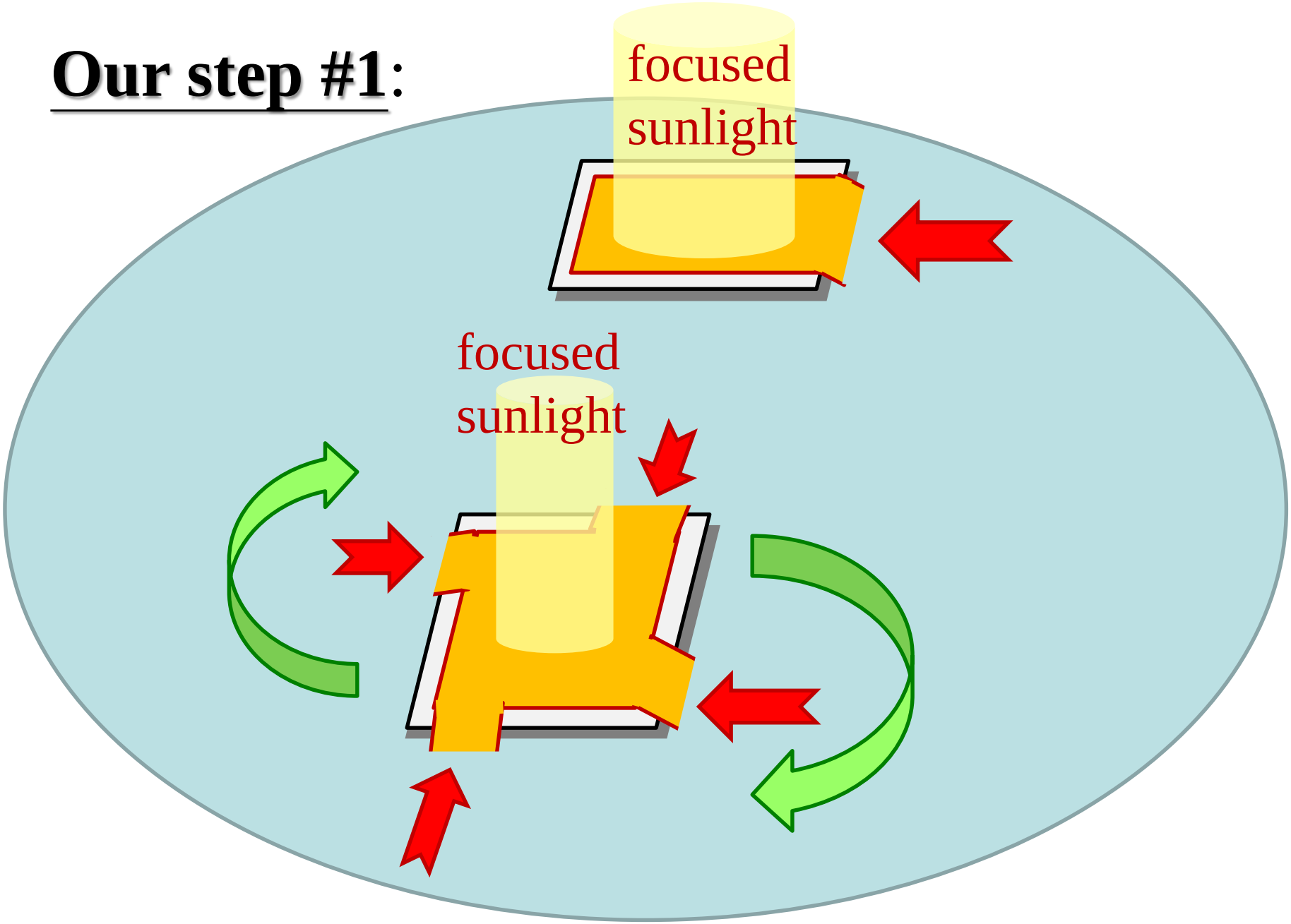
$$\boldsymbol{\tau}_{AB} = \hat{\mathbf{z}}\frac{\Delta\gamma}{6}\left[ab\cos(\theta_{AB}) + b^2 - 2a^2\right]$$

$$\boldsymbol{\tau}_{AC} = -\hat{\mathbf{z}}\frac{\Delta\gamma}{6}\left[ab\cos(\theta_{AC}) + b^2 - 2a^2\right]$$

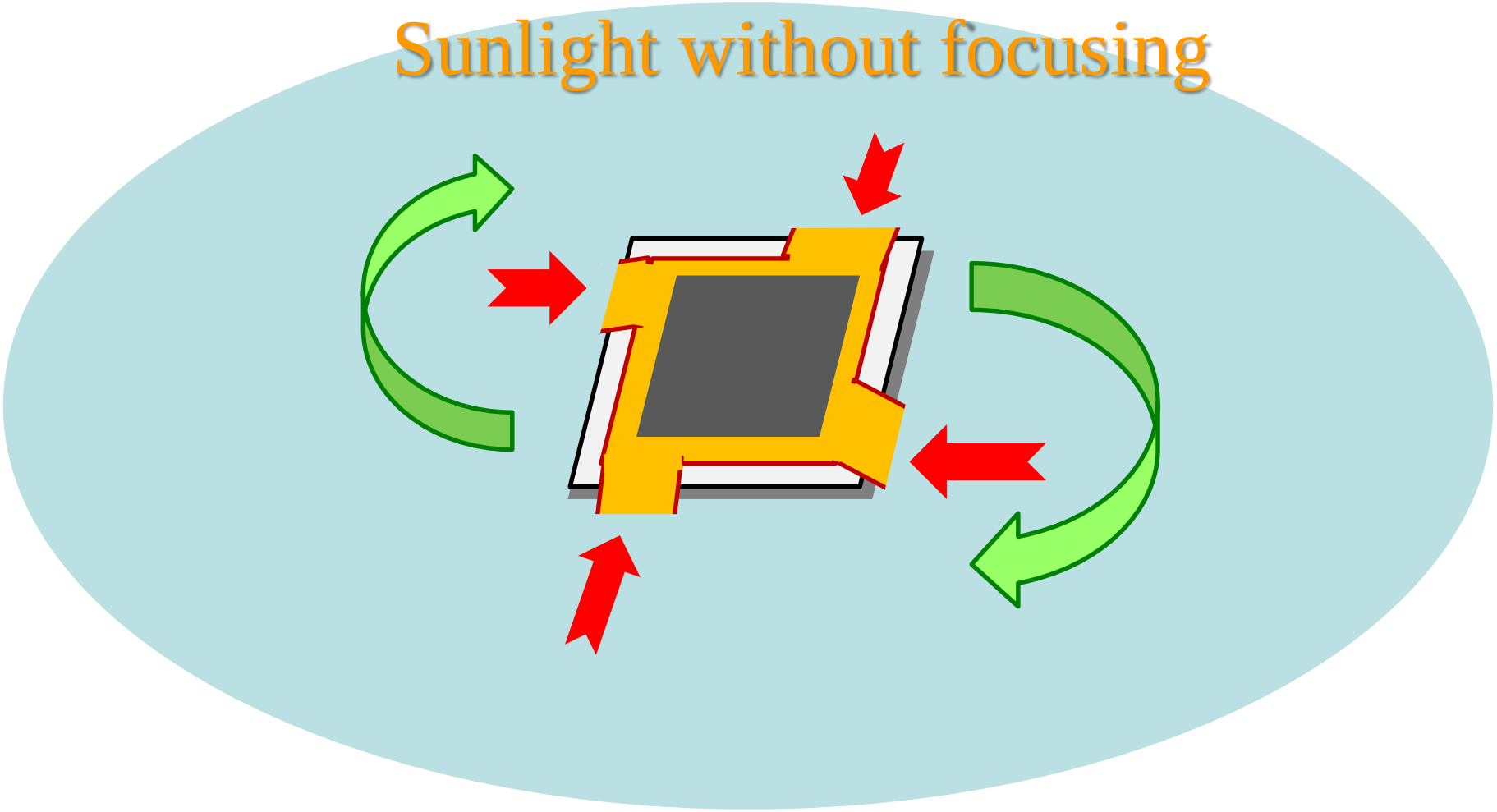
$$\boldsymbol{\tau} = \hat{\mathbf{z}}\,\Delta\gamma\,ab[1 - cos(\pi/3)]$$

Claudio Maggi, et.al., Nature Communications 8855 (2015)

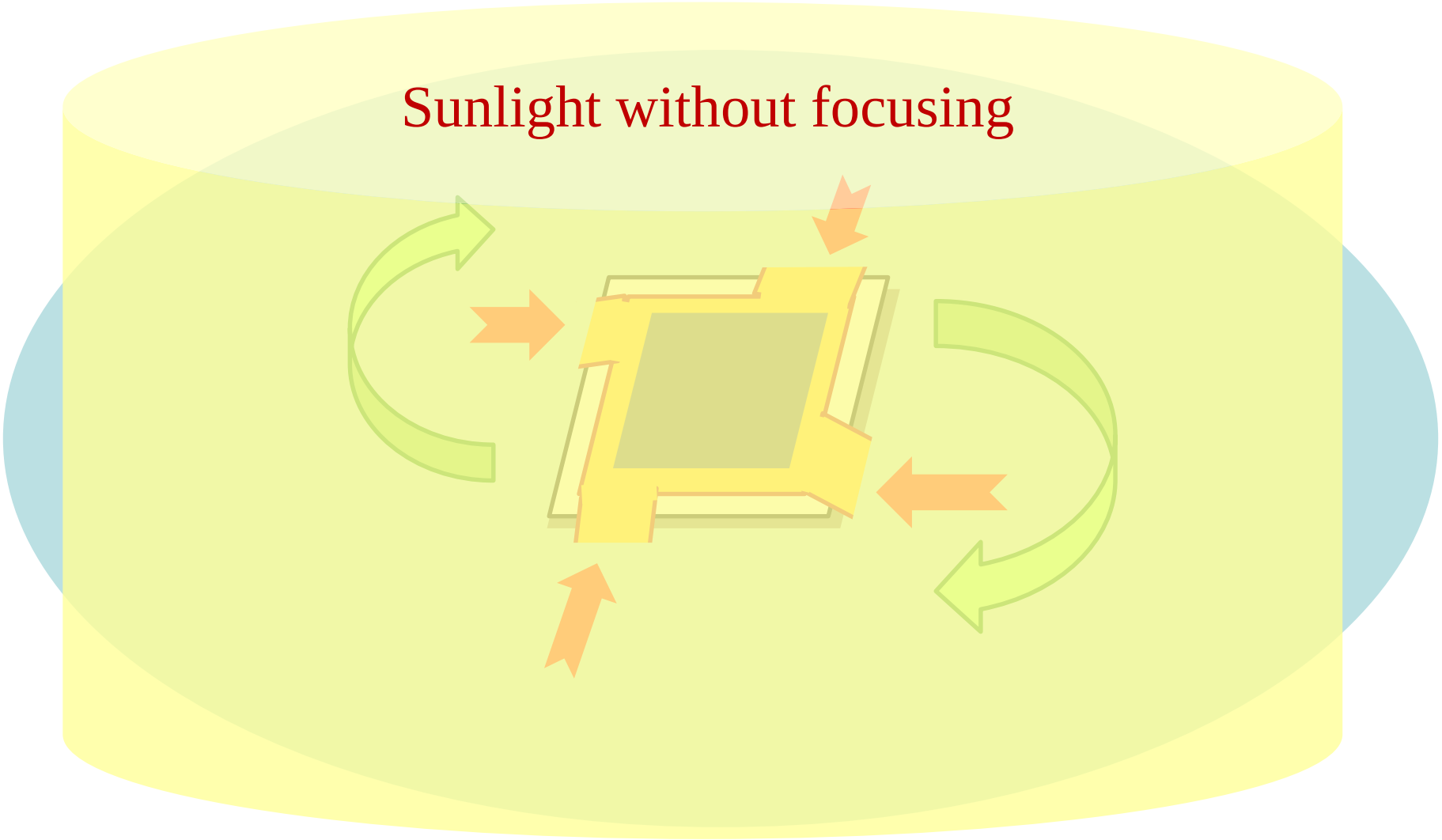
Our step #1:



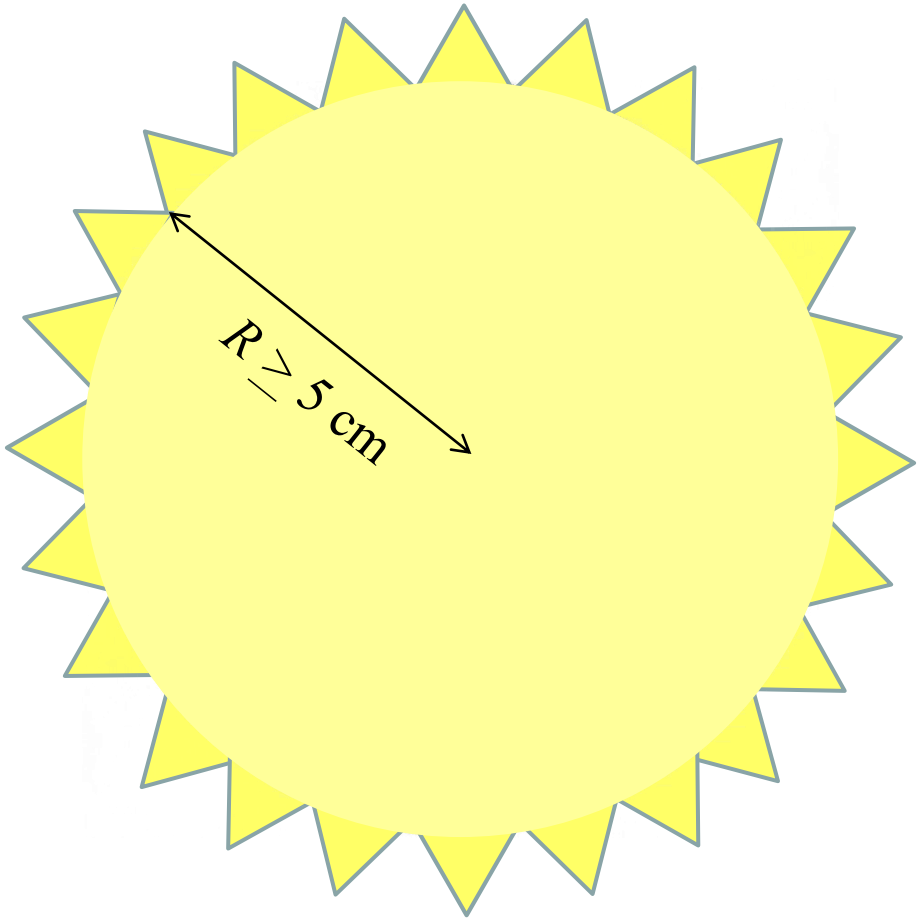
Our step #2:



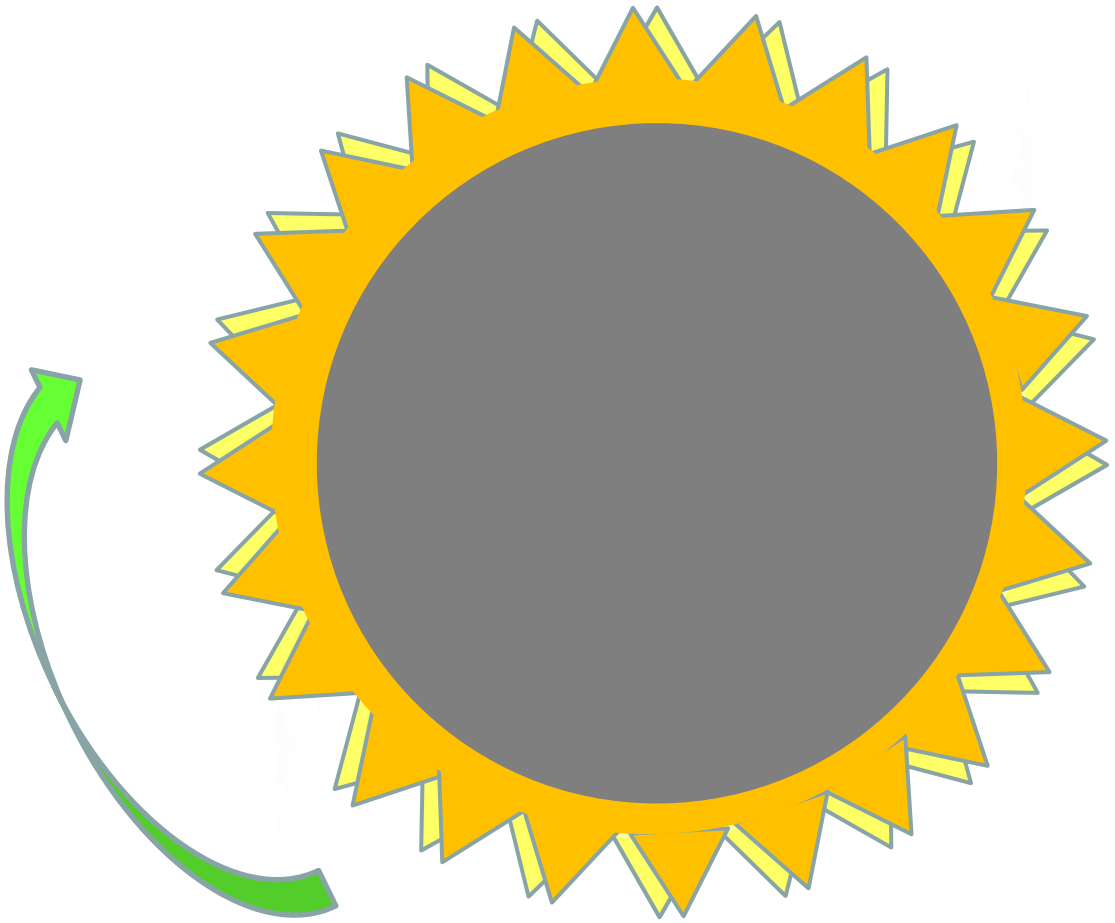
Our step #2:



Our step #3:



Our step #3:



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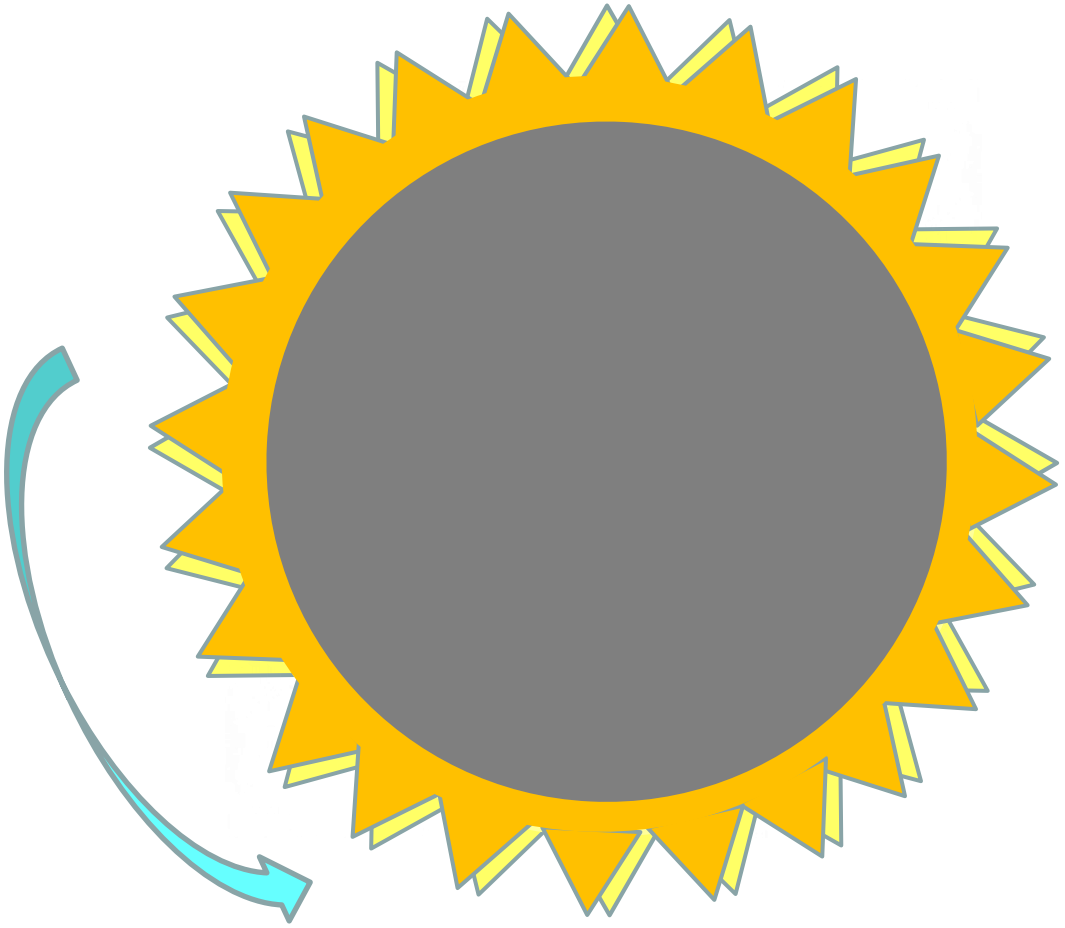
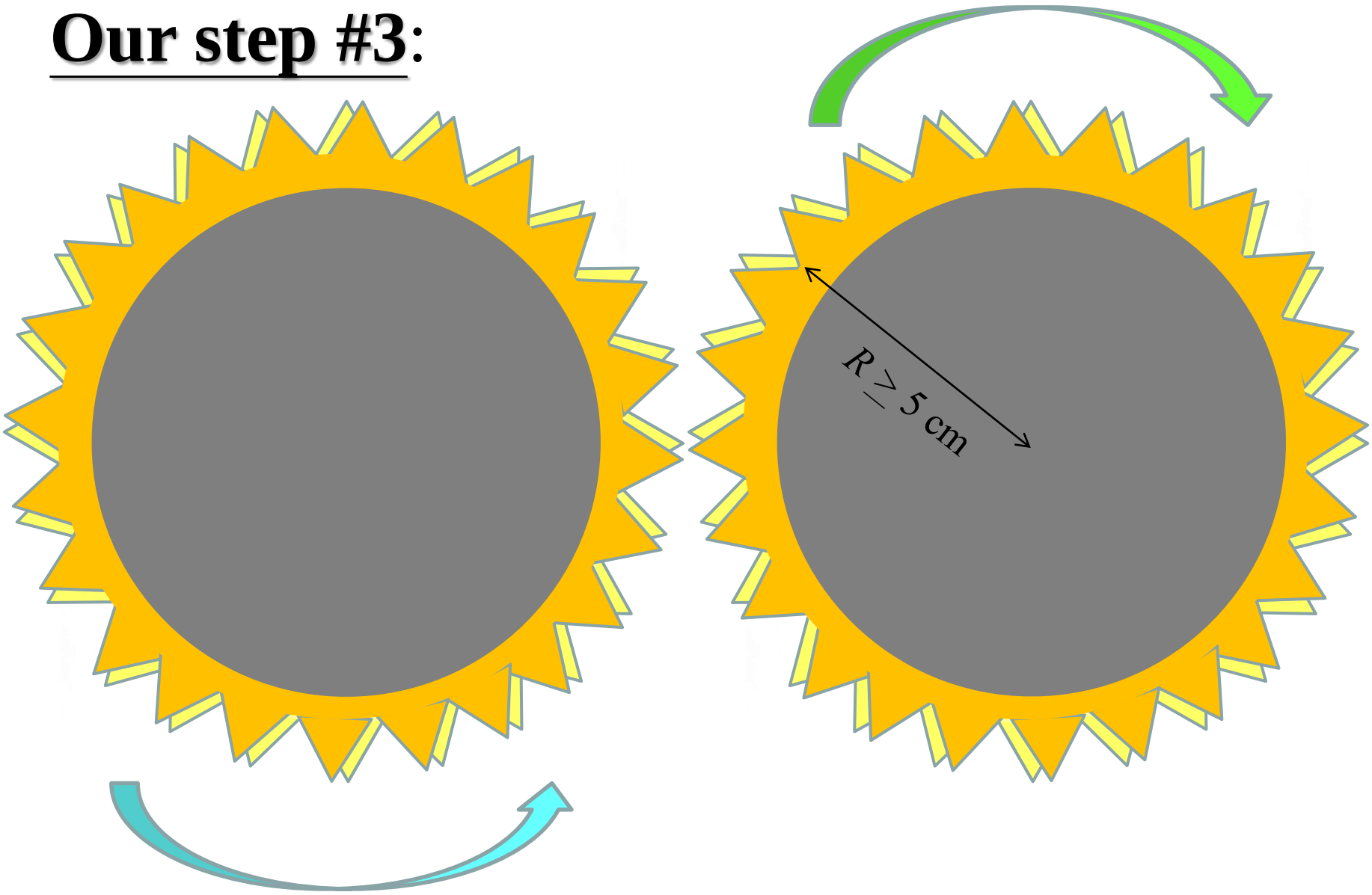


Our step #3:



首度提供一個設計的架構，可以只靠日光的直接照射而使得簡單的漂浮物體旋轉，並且其轉速會隨著照度的提高而增加，因此其實際應用的潛力至少可以包括：

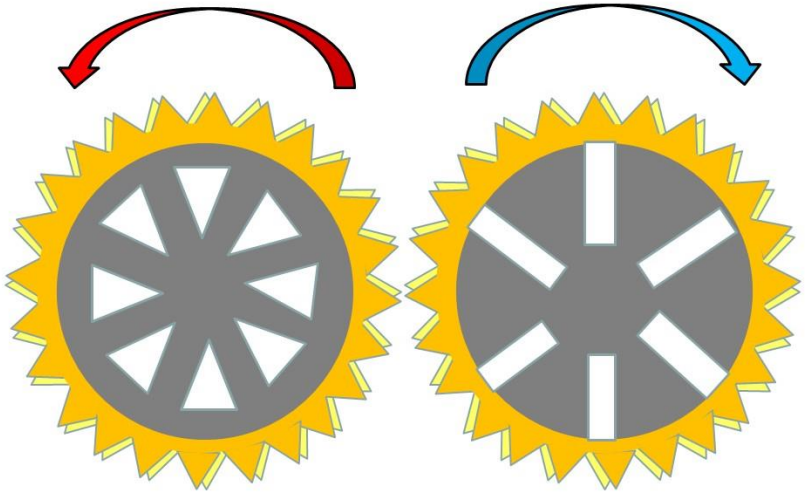
（一）自然科學和能源教育的啟發性實作教材及新穎太陽能玩具。

（二）光驅動馬達：透過大型化或集結整合的傳動設計 ➔「帶動發電」等應用。

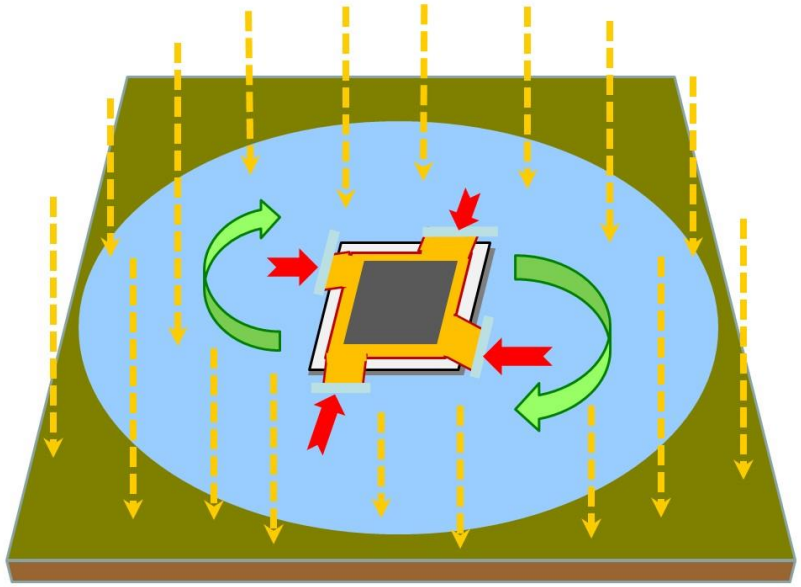
（三） 養殖農漁業設備：日光帶動的漂浮轉盤，提供攪水增氧或間歇遮蔽等功能。

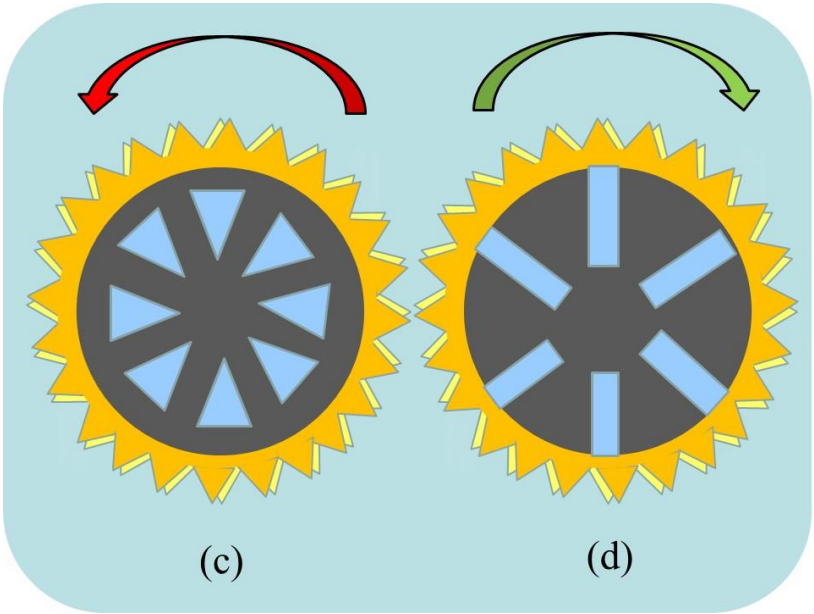
（四） 景觀工程/庭園造景器材：為戶外的靜態水池設施點綴動態的日光裝置藝術。

（五） 簡易型的日光照度計：校正後，即可透過轉速的測量而估算日光的照度。

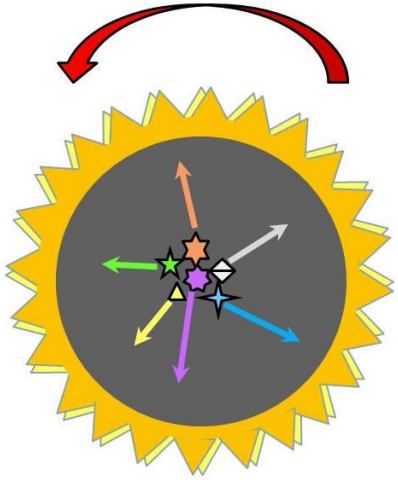


(a) (b)





(c) (d)



(e)

表面物理實驗室

表面上看起來，
好像物理實驗室