香港教育大學
The Education University of Hong Kong

FACULTY OF LIBERAL ARTS AND SOCIAL SCIENCES
博文及社會科學學院

科學與環境學系
Department of Science and Environmental Studies

2023-2024 Quality Education Fund Thematic Network - Tertiary Institutes

STEAM Education with Self-directed and Progressive Learning of Engineering Design Process for Problem-solving

透過STEAM教育自主及循序漸進學習以工程設計流程解難

物料顏色與散熱速度關係

迦密中學Carmel Secondary School

Author: POON TAK YIN

CHEN JUN TAO

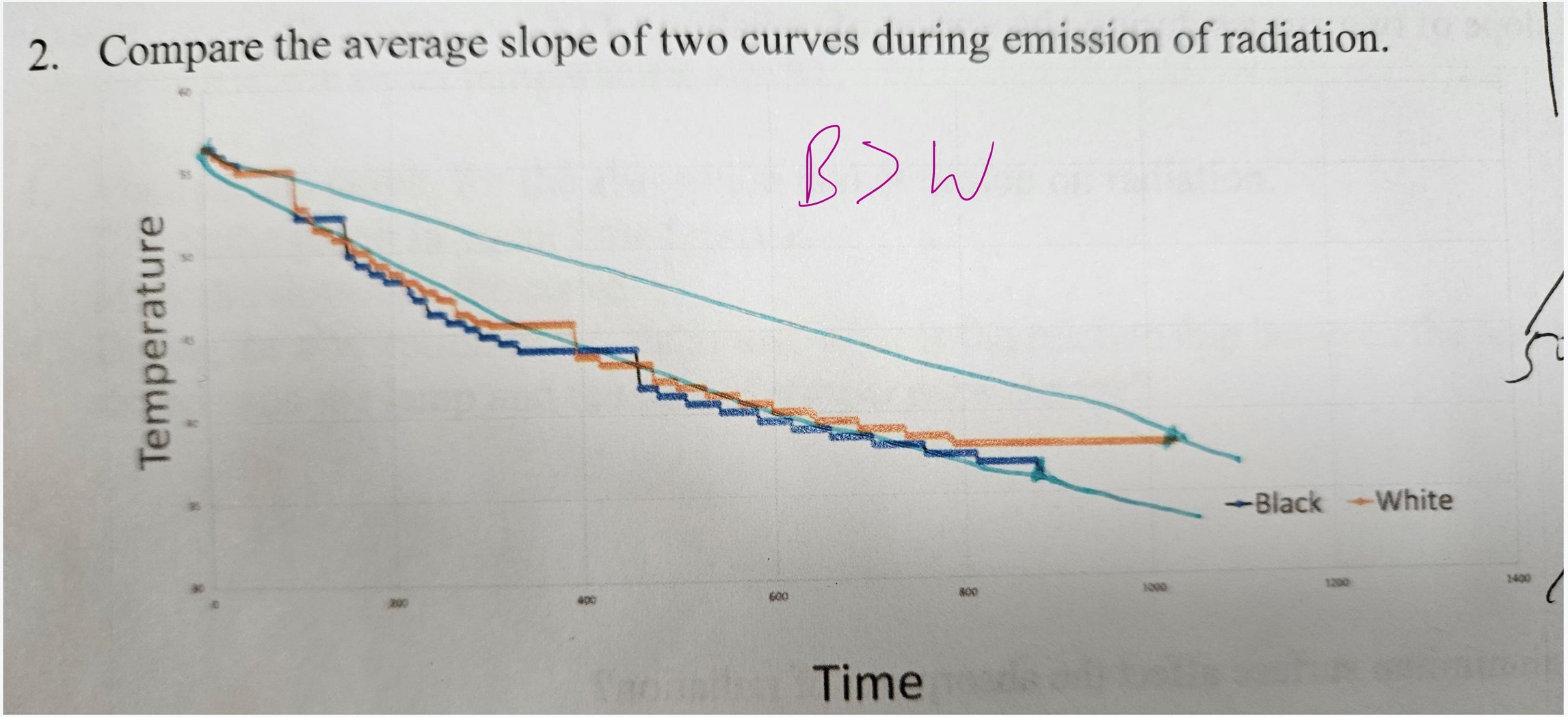
TANG LI LI

香港教育大學
The Education University of Hong Kong

觀察Observation

FACULTY OF LIBERAL ARTS AND SOCIAL SCIENCES
博文及社會科學學院

科學與環境學系
Department of Science and Environmental Studies



提問Question

- 黑色物料真的比白色物料散熱快嗎?
- 吸光與散熱性質好像不同?

理論Theory

- 對於輻射吸收，白色之所以白色，因為把顏色光都反射走了，彩色的集合變成白色。

- 黑色之所以黑色，因為把顏色光都吸收了，所以無反射光的物體呈現黑色。

理論Theory

- 相反，散熱可以分為傳導、對流、輻射
- 傳導和對流以Newton’s law of cooling為主
- 輻射散熱以Stefan-Boltzmann law為主

理論Theory

Conduction/Convection	Radiation
Newton's law of cooling	**Stefan-Boltzmann law**
傳熱速度與表面積和環境溫度差成正比	傳熱速度與表面積和自身温度四次方成正比

$$q = h\left(T(t) - T_{\text{env}}\right) = h\,\Delta T(t),$$

h = heat transfer coefficient

h of water = 500 to 10,000 W/(m²K).

T = temperature of the object's surface

T_{env} = temperature of the environment

$T(t)$ = time-dependent temperature

$$j^\star = \varepsilon\,\sigma\,T^4$$

$j^\star$ = black-body radiant emittance

σ = Stefan-Boltzmann constant

T = thermodynamic temperature

ε is the emissivity

$\sigma = 5.67 \times 10^{-8}$ W/(m²K⁴)

q 和 j* 都是以 W/m² 為單位
即每秒每平方米釋放的 Joule 能量

理論Theory

- 其實**Temperature difference** decay跟Natural Radioactive decay的公式一樣都是指數衰退exponential decay

(1.1)	$\Delta U = mc\Delta T$	(Heat capacity)
(1.2)	$\Delta U = \Delta Q - \Delta W$	(First law of thermodynamic)
(1.1)+(1.2)	$\therefore \Delta Q = mc\Delta T$	
(1.3)	$\dot{Q} = mc\dot{T}$	(heat flow into the body)
(1.4)	$q = h\Delta T(t)$	(newton's cooling law)
	$Q = \int_A q\, dA$	
(1.5)	$\dot{Q} = hA\Delta T(t)$	(heat flow out of the body)
(1.3)+(1.5)	$-mc\frac{dT}{dt} = hA\Delta T$	
	$\frac{dT}{\Delta T} = -\frac{hA}{mc}dt$	
	$ln(\Delta T) = -t/\tau + C$	Let $\tau = \frac{mc}{hA}$
(1.6)	$\Delta T = \Delta T(0)e^{-\frac{t}{\tau}}$	$\Delta T(0)$ refers to initial temperature difference
(1.7)	$T(t) = T_{env} + (T(0) - T_{env})e^{-\frac{t}{\tau}}$	

預測Hypothesis

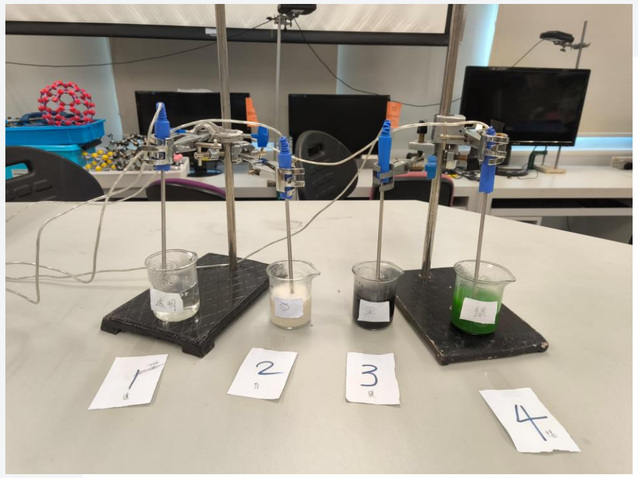
黑色比白色散熱快

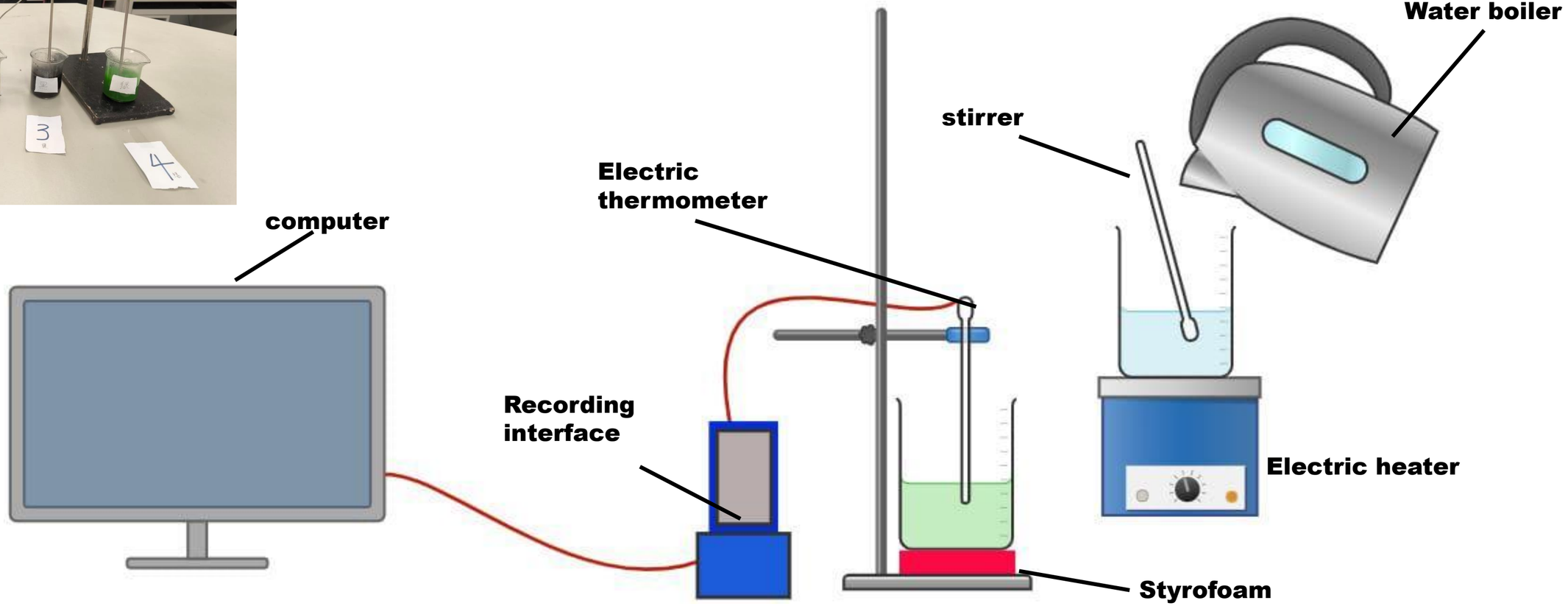
香港教育大學
The Education University of Hong Kong

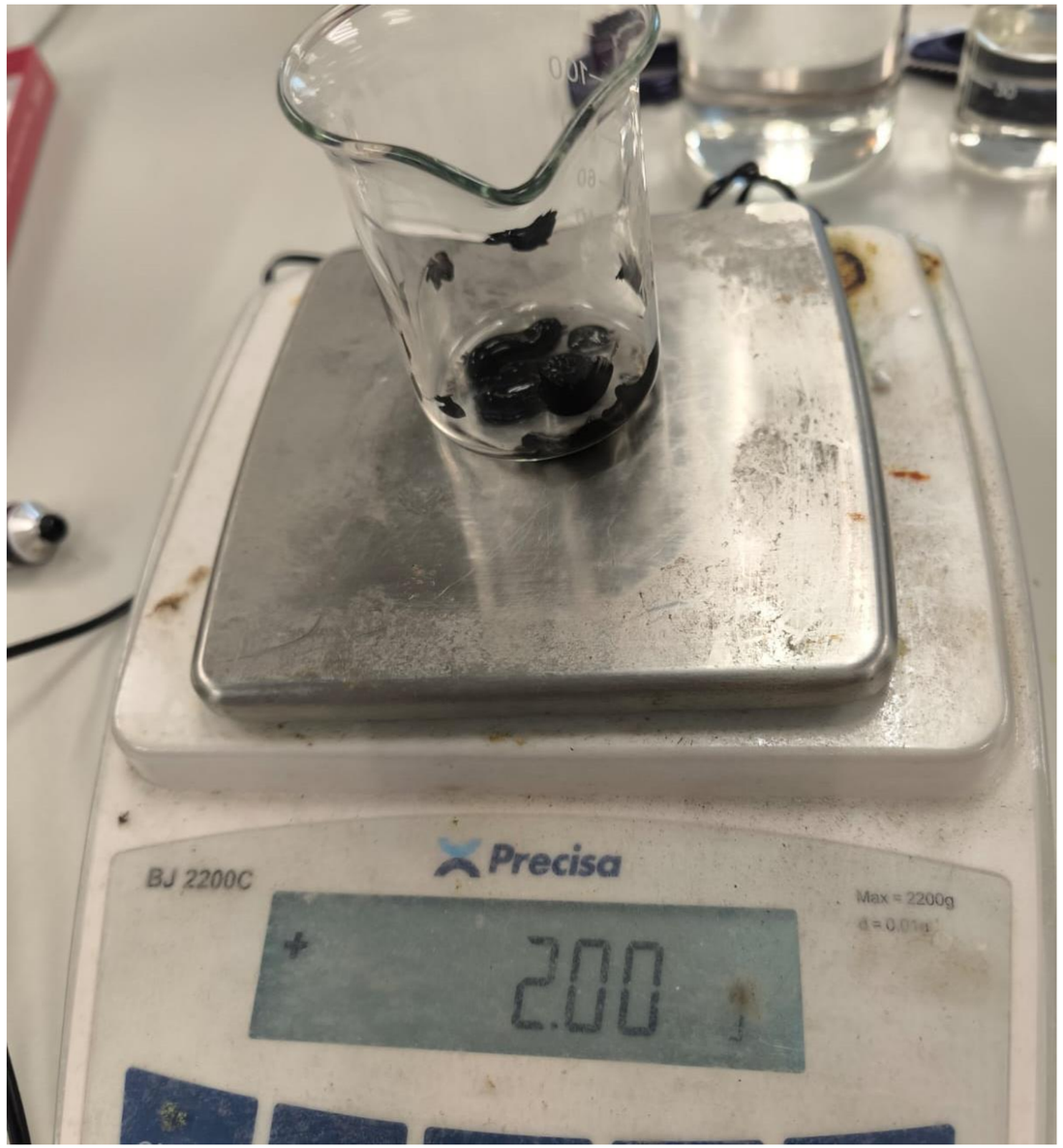
實驗設計流程

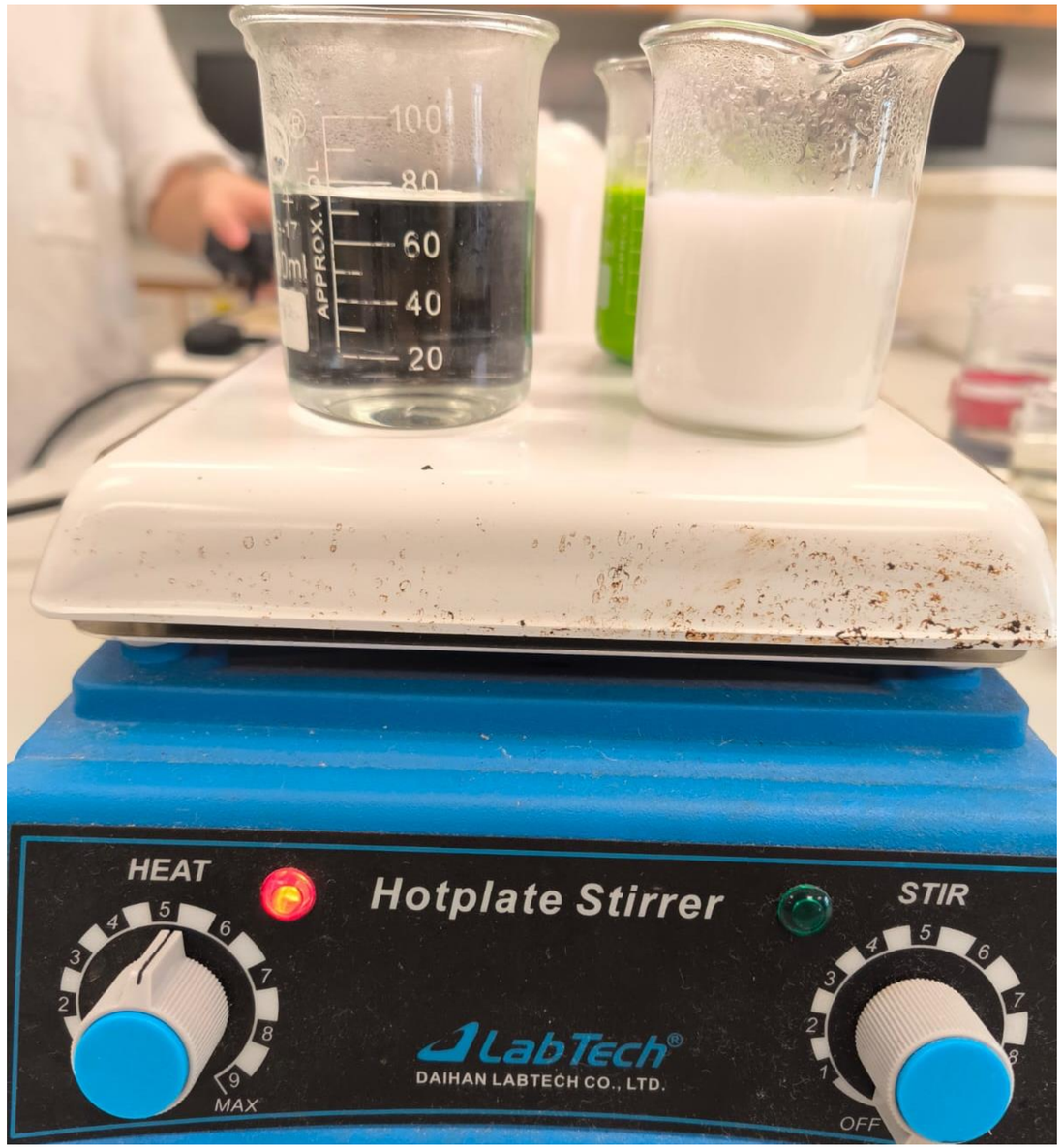
FACULTY OF LIBERAL ARTS AND SOCIAL SCIENCES
博文及社會科學學院

科學與環境學系
Department of Science and Environmental Studies





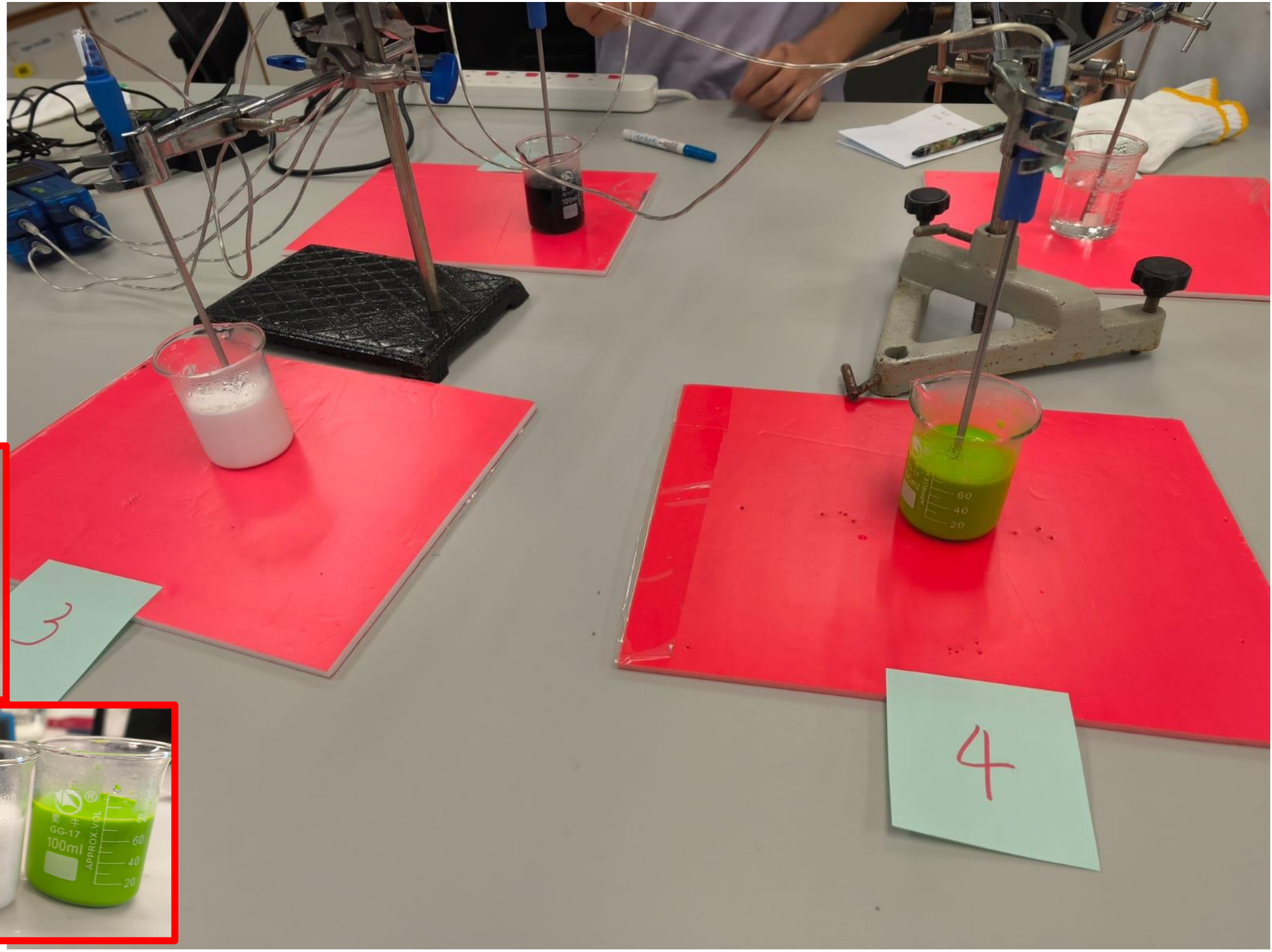

Precisa
BJ 2200C
Max = 2200g
2.00


100
80
60
40
20
HEAT
Hotplate Stirrer
STIR
LabTech®
DAIHAN LABTECH CO., LTD.
MAX
OFF


Xplorer GLX
Physics Lab
F1
F2
F3
F4
Esc


WATER COLOUR
341 YELLOW GREEN
150 TITANIUM WHITE
327 LAMP BLACK
UMAE
15ml e (0.5 U.S.fl.oz)


100
80
60
40
20
GG-17
100ml
APPROX. VOL

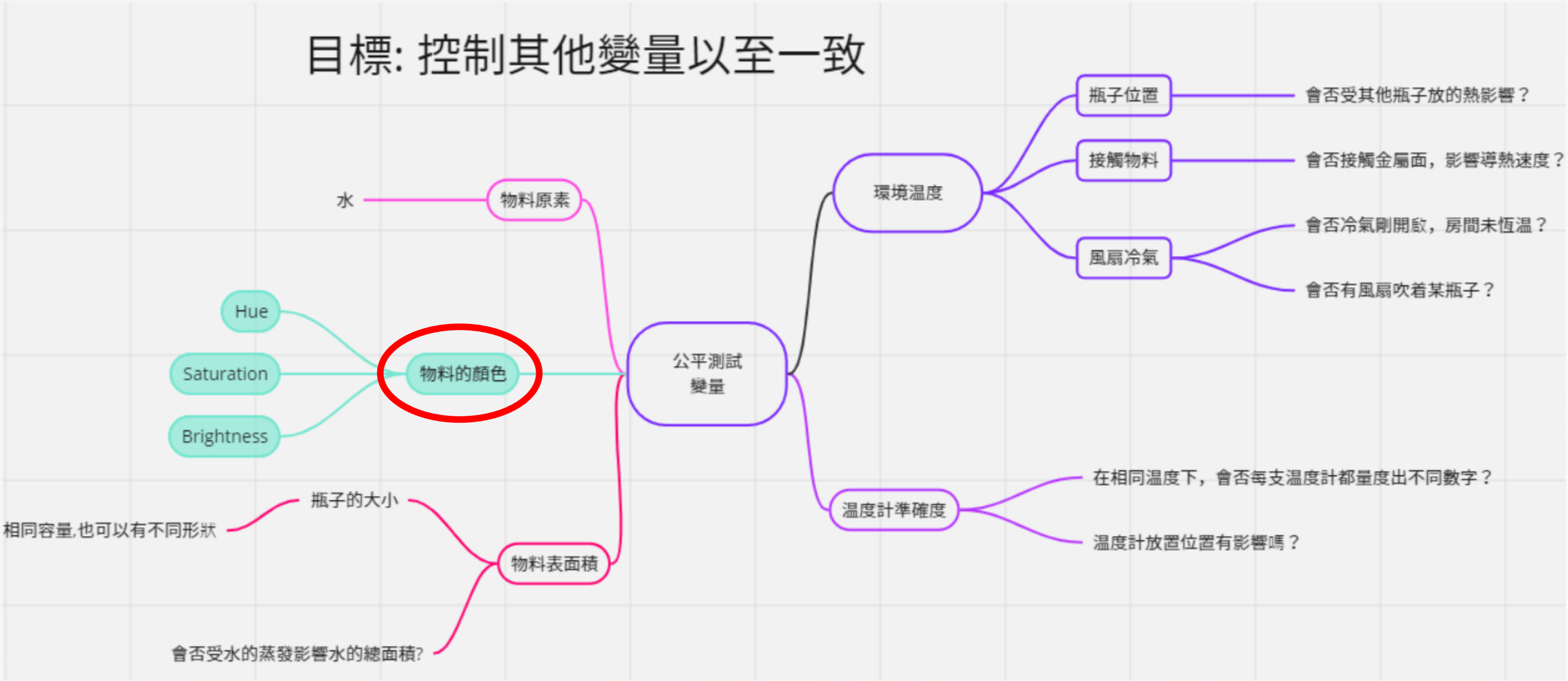

3
4

香港教育大學
The Education University of Hong Kong

FACULTY OF LIBERAL ARTS AND SOCIAL SCIENCES
博文及社會科學學院

科學與環境學系
Department of Science and Environmental Studies

公平測試

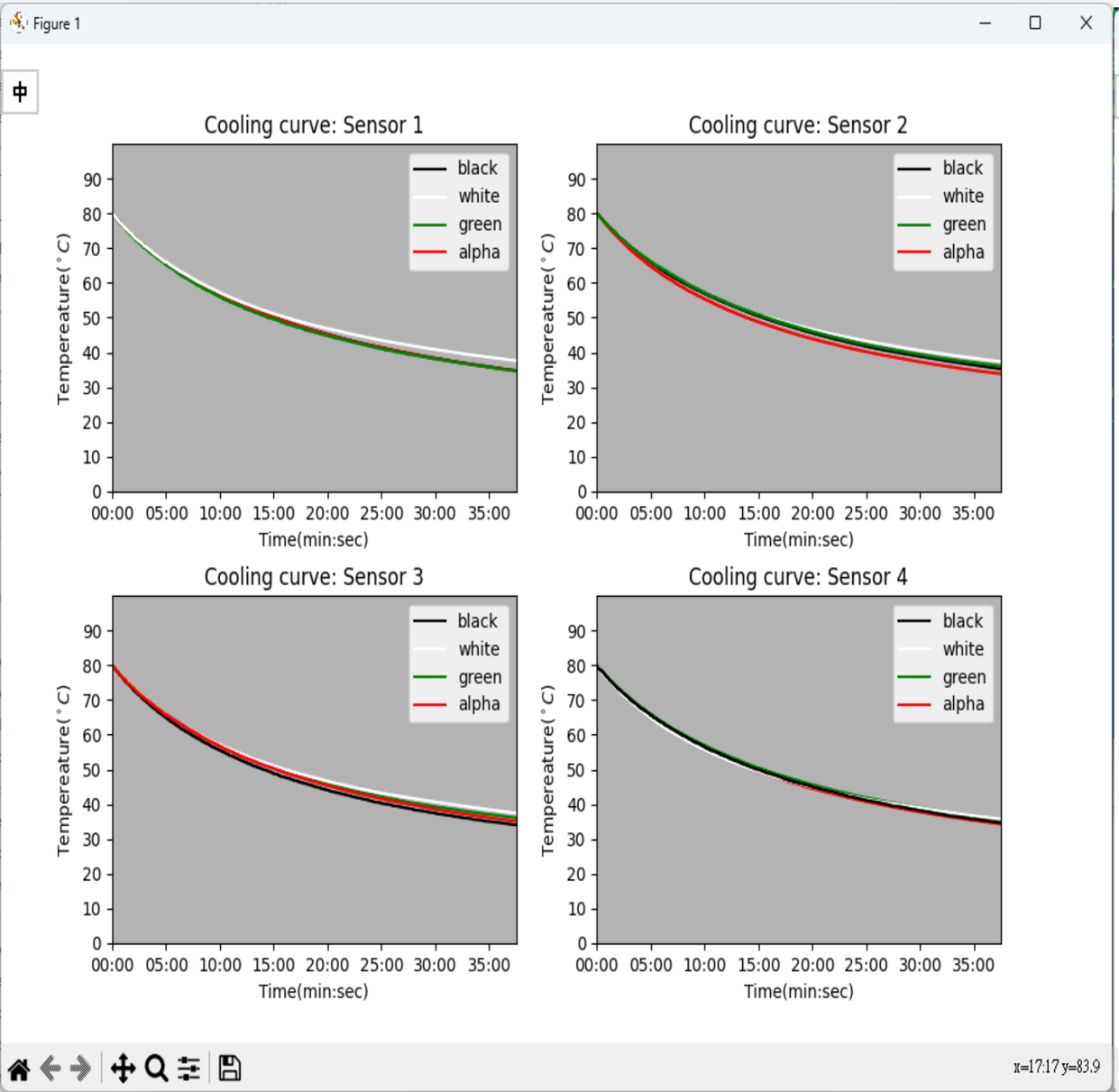


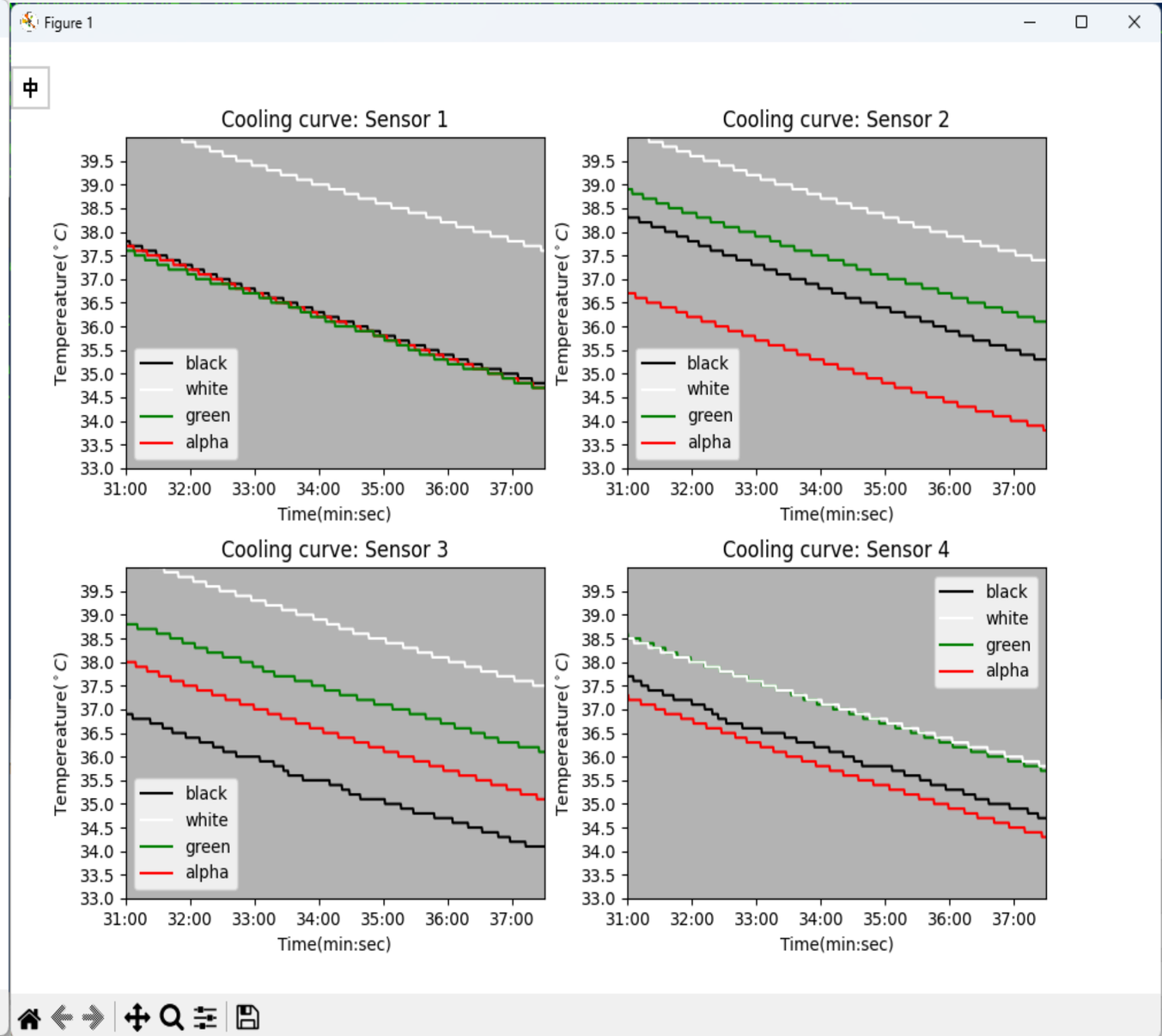
香港教育大學
The Education University of Hong Kong

實驗結果

FACULTY OF LIBERAL ARTS AND SOCIAL SCIENCES
博文及社會科學學院

科學與環境學系
Department of Science and Environmental Studies





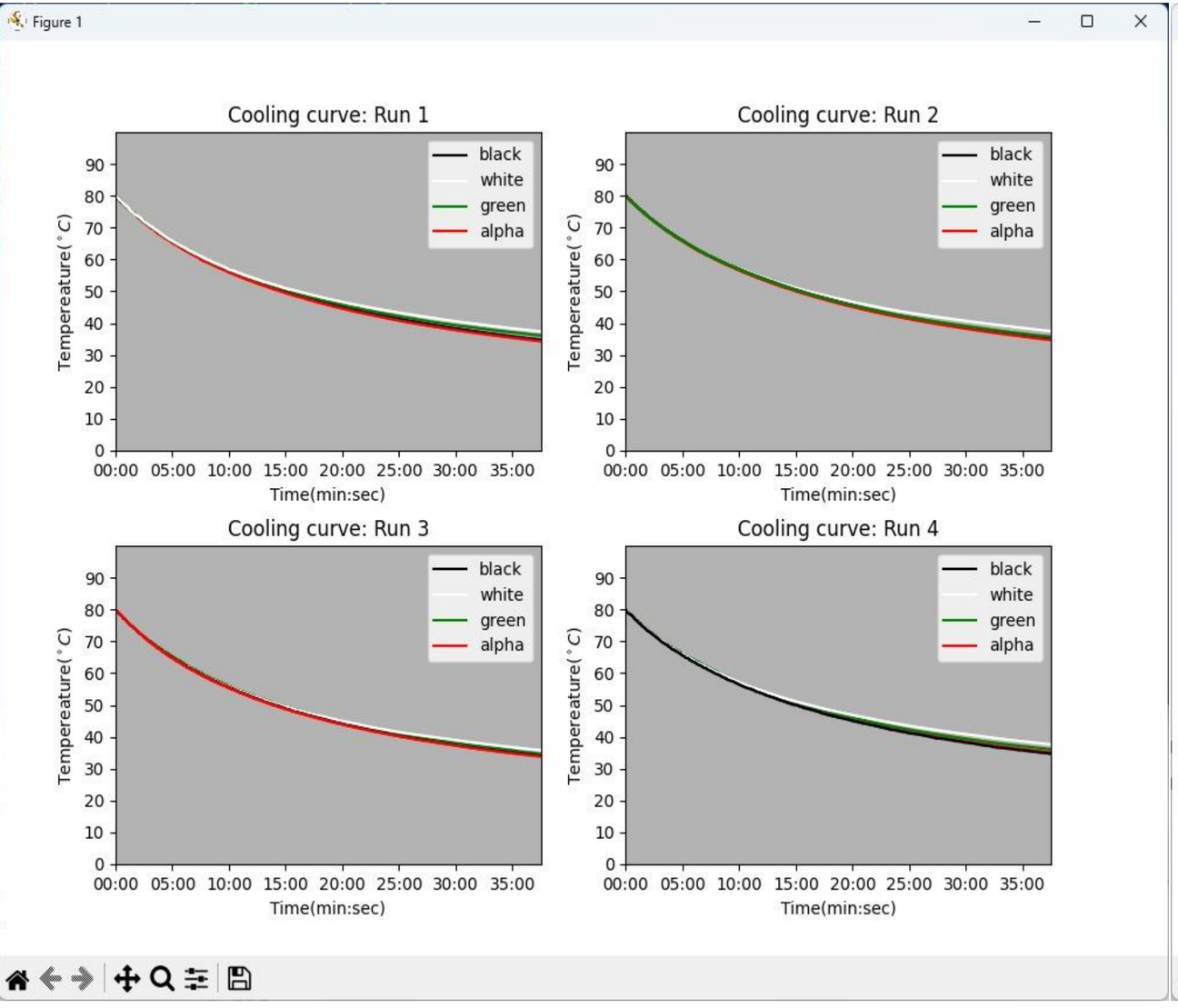


Figure 1
Cooling curve: Run 1
Cooling curve: Run 2
Cooling curve: Run 3
Cooling curve: Run 4
black
white
green
alpha
Tempereature(°C)
Time(min:sec)
00:00 05:00 10:00 15:00 20:00 25:00 30:00 35:00

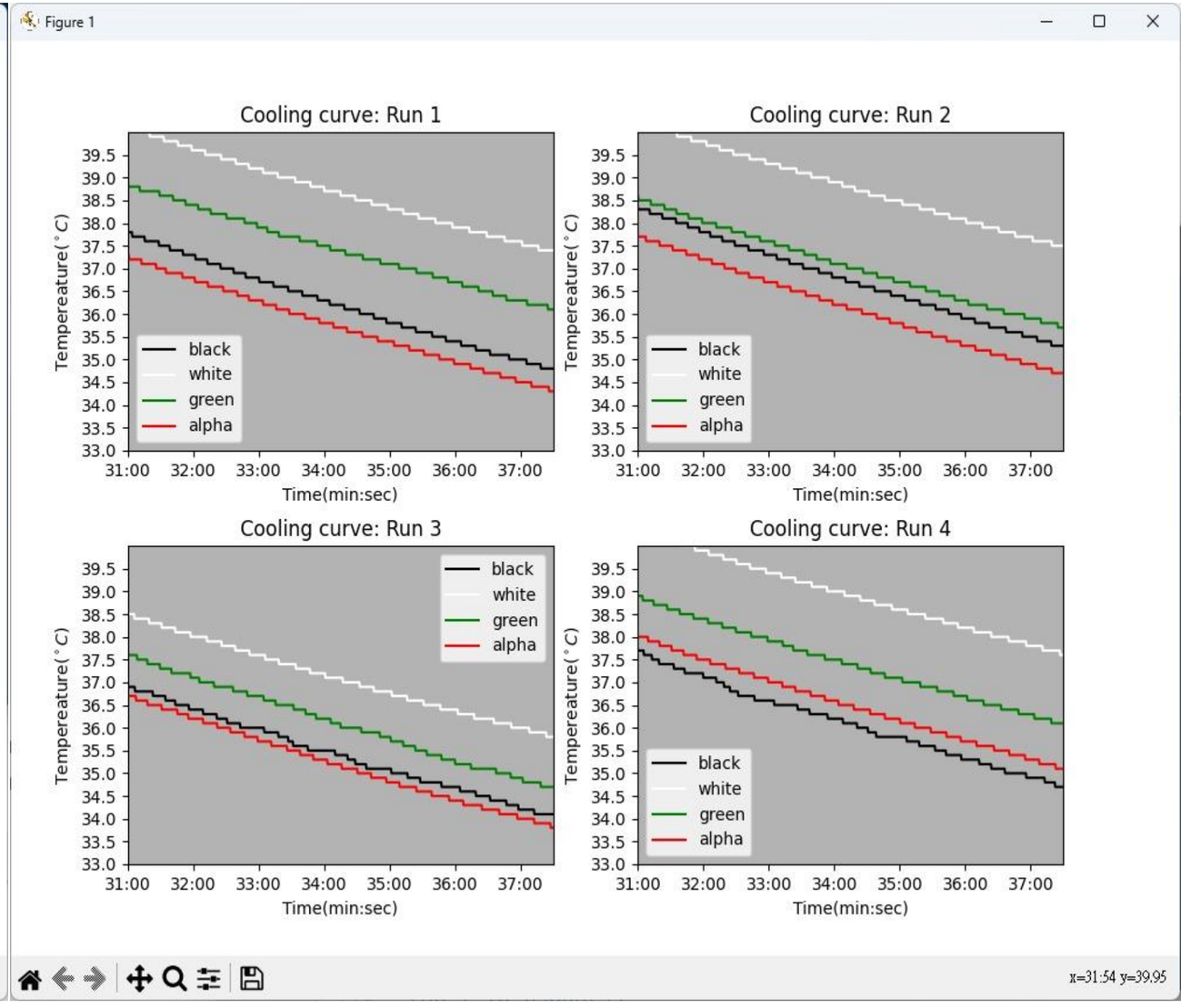


Figure 1
Cooling curve: Run 1
Cooling curve: Run 2
Cooling curve: Run 3
Cooling curve: Run 4
black
white
green
alpha
Tempereature(°C)
Time(min:sec)
31:00 32:00 33:00 34:00 35:00 36:00 37:00
x=31:54 y=39.95

理論Theory

Kirchhoff's law of thermal radiation

簡單而言:

- For an arbitrary body emitting and absorbing thermal radiation in thermodynamic equilibrium, the emissivity is equal to the absorptivity.
- **輻射放熱和輻射吸熱能力成正比關系**

$$\varepsilon_\lambda = \alpha_\lambda$$

Infrared Emissivity Table

Material	Emissivity
Snow/Ice	0.98 - 0.99
Aluminium/Copper (polished)	0.05
Paint: black	0.95
Paint: white	0.84

Source:https://www.thermoworks.com/emissivity-table/

```
starting_temp=80
temp_order=-1 #last:-1 first:0
#Same Sensor, Different time
#Sensor1
s1y3 = df['run1'].iloc[row_start:,4].astype(float).to_numpy() #Green
s1y3 = s1y3[np.where(s1y3==starting_temp)[0][temp_order]:np.where(s1y3==starting_temp)[0][temp_order]+row_end]
```

Column3
Green
温度 (攝氏度 °C)
80.2
80.2
80.2
80.1
80.1
80.1
80.1
80.1
80.0
80.0
80.0
79.9
79.9
79.9
79.8
79.8
79.8
79.7
79.7

- 假設設定起始温度為80度
- 出現多個80度數據
- 如何選擇起始格數?
- Temp_order為0時選第一格
- Temp_order為-1時選最尾一格
- 對結果有何影響?