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# 熱與氣體

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## 1. Temperature and Thermometers 溫度和溫度計

### "Must-understand" concepts

#### "必須理解" 的概念

- Temperature\* = measure the degree of hotness + a measure of the average kinetic energy of the particles in an object  
溫度 \* = 測量熱度 + 測量物體中粒子的平均動能
- Temperature scaling & Calibration\* – Upper fixed point = 100° C /Lower fixed point = 0° C  
溫度校準 \* – 高定點 = 100° C / 低定點 = 0° C
- Kelvin temperature = Celsius temperature + 273,  
i.e. 0K & -273° C = absolute zero (lowest possible temperature)  
絕對溫度 = 攝氏溫度 + 273，即 0 K 和 -273° C = 絕對零度（最低溫度）
- Thermometers – Thermometric property 溫度計 – 溫度特性 \*  
【= Physical property change with Temperature 物理特性隨溫度變化】

#### Examples 例子 : \*

- Liquid-in-glass: Expansion of the liquid  
玻璃液體：液體膨脹
- Rotary: Expansion of 2 different metals  
旋轉式：擴展兩種不同的金屬
- Resistance: Temperature increase  $\Rightarrow$  resistance of metal increase  
電阻：溫度增加 $\Rightarrow$ 金屬的電阻增加
- Thermistor: Temperature increase  $\Rightarrow$  resistance of resistor decrease  
熱敏電阻：溫度升高 $\Rightarrow$ 電阻降低
- Liquid crystal: Change color according to temperature change  
液晶：根據溫度變化而變色
- Infrared sensing: Temperature increase  $\Rightarrow$  increase the release of infrared radiation  
紅外感應：溫度升高 $\Rightarrow$ 增加紅外輻射的釋放

### "Should understand" concepts

#### " 應該理解 " 的概念

- Every matter is made up of atoms (and there are over 100 types of atoms, each type is called an element)  
每個物質都是由原子組成的（有一百多種原子，每種原子稱為元素）
- 2 or more atoms = molecules (e.g  $\text{H}_2\text{O}$ )  
兩個或更多原子 = 分子（例如  $\text{H}_2\text{O}$ ）
- Physical property of Solid vs Liquid vs Gas (e.g shape / volume / movement / P.E. difference)  
固體 vs 液體 vs 氣體的物理性質（例如形狀 / 體積 / 運動 / 勢能）

### "Must know" questions

#### " 必須知道 " 的問題

1. Describe how a liquid-in-glass thermometer can be calibrated. \*  
描述如何校準玻璃液體溫度計。 \*

Ans 答案：

【At standard atmospheric pressure 在標準大氣壓力下】

- Step 1 : Put the thermometer in pure melting ice and mark the liquid level (lower fixed point) as  $0^\circ\text{C}$ .  
第 1 步：將溫度計放在純融冰中，並將液位（下固定點）標記為  $0^\circ\text{C}$ 。
- Step 2: Put the thermometer in pure boiling water and mark the liquid level (upper fixed point) as  $100^\circ\text{C}$ .  
第 2 步：將溫度計放在純沸水中，並將液位（上固定點）標記為  $100^\circ\text{C}$ 。
- Step 3: Divide the interval between 2 marks into 100 equal divisions.  
第 3 步：將 2 個標記之間的間隔劃分為 100 個相等的劃分。

### "Good to know how to do" questions

#### " 可以嘗試 " 的問題

1. The advantages & disadvantages of using alcohol & mercury type of liquid-in-glass thermometer.

使用酒精和水銀類型的玻璃液溫度計的優 / 缺點。

Ans 答案：

- Alcohol: Non-toxic / Flammable

酒精：無毒 / 易燃

- Mercury: Faster response / Toxic

水銀：反應速度更快 / 有毒

2. Sensitivity of liquid-in-glass thermometer (able to detect small temp. changes) \*

玻璃液溫度計的靈敏度（能夠檢測微小的溫度變化） \*

Ans 答案：

- Increase the bulb size.

增加泡的尺寸。

- Use a narrow capillary tube.

使用狹窄的細管。

## Temperature and Thermometers 溫度和溫度計

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3. Responsiveness of liquid-in-glass thermometer (fast response to temp. change) \*

玻璃液溫度計的反應能力（快速反應溫度變化） \*

Ans 答案：

- Use mercury  
使用水銀。
- Use thinner tube wall  
使用較薄的管壁。

## 2. Heat and Internal Energy

### 熱與內能

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#### "Must-understand" concepts

##### "必須理解" 的概念

- What is "Internal energy" of an object?

什麼是物體的 " 內能 " ？

- It is the total kinetic energy and potential energy in an object. \*

" 內能 " 是物體的總動能 + 勢能。\*

\*Energy is measured in Joule (J).

\* 能量以焦耳 (J) 為單位。

- The factors that can affect the level of Internal Energy of an object: \*

可以影響物體內能的因素：\*

- Temperature (KE): determine the average K.E of its particles.

溫度（動能）：其粒子的平均動能。

- States (PE): solid < liquid < gas state

狀態（勢能）：固態 < 液態 < 氣態

- Materials: Different materials can have different potential energy in nature.

材料：不同的材料可以具有不同的勢能。

- Size: the larger the size of an object, the higher the sum of KE & PE.

大小：物體的體積越大，動能和勢能的總和越高。

- You can increase an object's internal energy by "heating" it or "doing work" on it.

您可以通過 " 加熱 " 或 " 作功 " 來增加物體的內能。

- What is "Heat"?

什麼是 " 熱 " ？

⇒ It is not an energy that can be stored in an object.\*

不是存儲在物體中的能量。\*

⇒ Heat is an energy transfer process between objects because of their temperature difference.

熱是因物體溫差，物體之間能量傳遞的過程。

Therefore 因此，

- When two objects with different temperature contact, there will be a net heat transfer from high temperature object to low temperature object, until they reach the same temperature.

當兩個溫度不同的物體接觸時，高溫物體會向低溫物體傳遞熱，直到它們達到相同的溫度。

- When two objects with same temperature contact, the net heat transfer will be 0 (= Thermal Equilibrium). Therefore, they will remain at the same temperature.

當兩個具有相同溫度的物體接觸時，它們之間仍然存在熱傳遞，但是淨熱傳遞將為 0(= 熱平衡)。因此，它們將保持相同的溫度。

- The Law of Conservation of Energy – Energy can be transferred from a body to another (or to another energy form), but it cannot be created or destroyed.

能量守恆定律 – 能量可以從一個物體轉移到另一個物體（或其他能量形式），但不能被創造或破壞。

\*If assuming no heat lost to surroundings,

\* 如果假設沒有熱損失到周圍環境，

⇒ Heat lost by hot object = Heat gain by cold object

高溫物體的熱量損失 = 低溫物體的熱量增加

$$\Rightarrow m_x c_x (\Delta T_x) = m_y c_y (\Delta T_y)$$

## Heat and Internal Energy 熱與內能

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- Power = Energy (J)/ time (s), it is measured as watt (W).

功率 = 能量 (J) / 時間 (s) , 以瓦特 (W) 表示。

$$- 1 \text{ kWh ( 千瓦時 )} = 1 * 1000 * 3600 \text{ J} = 3.6 \times 10^6 \text{ J}$$

- Heat capacity (C, the energy required for a particular object to raise 1° C)

熱容量 (C, 特定物體升高 1° C 所需的能量 )

$$C = \frac{Q}{\Delta T}, \text{ its unit is 其單位為 } \text{J}^\circ \text{C}^{-1}$$

- Specific heat capacity (c, the energy required for a 1kg of particular object to raise 1° C)

比熱容 (c, 一公斤特定物體升高 1° C 所需的能量 )

$$c = \frac{Q}{m \Delta T}, \text{ its unit is 其單位為 } \text{J}^\circ \text{C}^{-1} \text{kg}^{-1}$$

$$C = m * c$$

- Energy efficiency of a device 裝置的效率：

$$- \text{Efficiency} = \left[ \frac{\text{Useful energy output}}{\text{Total energy input}} \right] \times 100\%$$

$$\text{效率} = \left[ \frac{\text{有用的能量輸出}}{\text{能量輸入}} \right] \times 100\%$$



### "Should understand" concepts

#### "應該理解" 的概念

- \*Higher the temperature difference, the faster the heat transfer rate.  
\* 溫差越大，傳熱速率越快。
- Joulemeter & kilowatt-hour meter are used to measure the electrical energy used by a device.  
焦耳表和千瓦時表是用於測量裝置使用的電能。
- Water – with a high specific heat capacity 水 – 高比熱容 ( $4200 \text{ J } ^\circ \text{C}^{-1} \text{kg}^{-1}$ ) \*
  - ⇒ Absorbing more energy per 1 kg  
每 1 公斤吸收更多的能量
  - ⇒ Absorbing same amount of energy with less mass required  
以更少的質量吸收相同量的能量

Therefore, it can be... 因此，它可以 ...

- Machinery coolant  
機械冷卻液
  - Maintain our body temperature  
保持體溫
  - Regulate temperature: Sea can slow down the temperature changes nearby  
調節溫度：海洋可以減慢附近的溫度變化
- ⇒ coastal areas have colder summers and warmer winters than the mainland.  
沿海地區夏季比大陸涼爽，冬季暖和。

### "Must know" questions

#### " 必須知道 " 的問題

1. When 2 objects are at the same temperature,  
當兩個物體處於相同溫度時，
  - Do they have the same amount of total kinetic energy?  
它們具有相同的動能嗎？
  - Do they have the same amount of potential energy?  
它們具有相同的勢能嗎？
  - Do they have the same amount of internal energy?  
它們具有相同的內能嗎？
  - Do their particles move at the same average speed?  
它們的粒子是否有相同的平均速度？

Ans 答案：No 否，No 否，No 否，No 否

2. When 2 objects with identical mass are having the same amount of internal energy,  
當兩個質量相同的物體具有相同的內能時，
  - Do they have the same temperature?  
它們是否具有相同的溫度？

Ans 答案：No 否

3. When 2 identical objects 【made by the same material, with identical mass】 , are having the same amount of internal energy,  
當兩個相同的物體 【由相同的材料製成，相同的質量】 具有相同的內能時，
  - Do they have the same temperature?  
它們是否具有相同的溫度？
  - Do they have the same amount of potential energy & kinetic energy?  
它們是否具有相同的動能及勢能？

Ans 答案：Yes 是，Yes 是

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## Heat and Internal Energy 熱與內能

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4. When blocks X & Y are in contact with each other, the heat flows from X to Y.

當木塊 X 和 Y 彼此接觸時，熱量從 X 流動到 Y。

- Does X have a higher amount of initial total kinetic energy than Y?  
X 是否具有比 Y 高的初始總動能？
- Does X have a higher amount of initial average kinetic energy of particles than Y?  
X 的粒子初始平均動能是否比 Y 高？
- Does X have a higher amount of initial internal energy than Y?  
X 的初始內部能量是否比 Y 高？

Ans 答案：No 否，Yes 是，No 否

5. Given block X has a higher initial internal energy than Y, then blocks X & Y are in contact with each other.

當木塊 X 的初始內部能量高於 Y，然後 X 和 Y 彼此接觸。

- The internal energy of block X must decrease after contact with Y?  
與 Y 接觸後，X 的內能將會降低？

Ans 答案：No 否

6. Given 5kg of object A and 3kg of object B are having the same heat capacity,

假設 5kg 的物體 A 和 3kg 的物體 B 具有相同的熱容量，

- Do they increase their temperature at the same rate when being heated by the same heater?  
當用同一加熱器加熱時，它們是否以相同的速率升高溫度？
- Do they have the same specific heat capacity?  
它們具有相同的比熱容嗎？

Ans 答案：Yes 是，No 否

7. Two blocks A and B of the same mass and of initial temperatures  $50^{\circ}\text{C}$  and  $40^{\circ}\text{C}$  respectively are in contact. The heat capacity of A is smaller than B. Assume no heat loss to surroundings. At steady state,

兩個質量相同的木塊 A 和 B，初始溫度分別為  $50^{\circ}\text{C}$  和  $40^{\circ}\text{C}$  進行接觸。  
木塊 A 的比熱容小於木塊 B。假定沒有熱損失到周圍環境。在穩定狀態下，

- Do their final temperature become the same?  
他們的最終溫度是否一樣？
- Do their final temperature become higher/lower/ equal to  $45^{\circ}\text{C}$ ?  
它們的最終溫度是否升高 / 降低 / 等於  $45^{\circ}\text{C}$  ？

Ans 答案：Yes. Lower than  $45^{\circ}\text{C}$ . 是。低於  $45^{\circ}\text{C}$ 。

8. Temperature - time graph questions

溫度 - 時間圖問題

Slope comparing:

斜率比較：

- Compare specific heat capacity if 2 objects are in same mass  
兩個物體質量相同，則比較比熱容
- Compare heat capacity of 2 objects are in different mass  
兩個物體質量不同，則比較熱容量

### "Good to know how to do" questions

#### " 可以嘗試 " 的問題

1. \*Experimental setup type questions – usually with information like joulemeter, immersion heater, temperature-time graph, energy-time graph, and ask you to  
\* 實驗設置類型的問題 – 通常帶有焦耳計，浸入式加熱器，溫度 - 時間圖，能量 - 時間圖等信息，並要求您
  - Calculate mass/temperature/heat capacity or specific heat capacity of an object  
計算物體的質量 / 溫度 / 熱容或比熱容
  - Calculate the power of the heater, the efficiency of the heater  
計算加熱器的功率，加熱器的效率
  - Your expectation to the result in reality (with heat loss to the surroundings)  
您對現實結果的期望（熱損失到周圍環境）
  - Mistakes the experiment have made & Possible ways to improve the experiment  
實驗所犯的錯誤和改進實驗的可能方法

### 3. Change of State

#### 熱與內能

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#### "Must-understand" concepts

#### "必須理解" 的概念

- You should already know the meaning of "solid, liquid, gas", "melting point", "boiling point".  
您應該已經知道 " 固體，液體，氣體 "，" 熔點 "，" 沸點 " 的含義。
- Latent heat = the energy transferred to an object to change its state, with no change in temperature.  
潛熱 = 傳遞給物體以改變其態而沒有溫度變化的能量。
- Specific latent heat of vaporization  
汽化比潛熱
$$l_v = \frac{Q}{m}$$
- \*Specific latent heat of vaporization 汽化比潛熱 =  $2.26 \times 10^6 \text{ J kg}^{-1}$
- Specific latent heat of fusion  
熔解比潛熱
$$l_f = \frac{Q}{m}$$
- \* Specific latent heat of fusion 熔解比潛熱 =  $3.34 \times 10^5 \text{ J kg}^{-1}$
- Only P.E change during the change of state, not the temperature (= avg K.E.) \*  
在物態變化過程中，只有勢能變化，而溫度（平均動能）則沒有變化 \*
- P.E level: Gas > Liquid > Solid, for the constant mass of the same matter.  
對於相同質量的相同物質，勢能：氣體 > 液體 > 固體。

## Change of State 狀態變化

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### "Should understand" concepts

#### " 應該理解 " 的概念

- Condensation occurs when changing gas to liquid state, releasing latent heat of vaporization.  
當氣體變為液態時，會發生凝結，釋放出汽化比潛熱。
- Freezing occurs when changing liquid to solid state, releasing latent heat of fusion.  
凝固，發生在將液體變為固體時，釋放出熔解比潛熱。
- Condensation has a warming effect to you; Evaporation is a cooling effect to you.  
凝結會帶來變暖的作用；蒸發會帶來冷卻的作用。

### "Must know" questions

#### " 必須知道 " 的問題

1. If 1 kg of water steam at  $100^{\circ}\text{C}$  is mixed with 1 kg of melting ice at  $0^{\circ}\text{C}$  in a sealed container, assuming no heat lost to the surroundings, what is the final weight of water steam, water and ice?  
如果在密封的容器中將 1kg  $100^{\circ}\text{C}$  的水蒸汽與 1kg  $0^{\circ}\text{C}$  的融冰混合，並假設沒有熱量散失到周圍，那麼水蒸汽，水和冰的最終重量是多少？

## Change of State 狀態變化

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### 2. Experimental setup questions – for finding the specific latent heat of vaporization/fusion\*

實驗設置問題 – 用於查找特定的汽化 / 融合潛熱 \*

- Explain whether you should use stirrer/lid/thermometer  
說明應否使用攪拌器 / 蓋子 / 溫度計
- How water steam condenses on beaker/spills out may affect the result  
水蒸汽在燒杯上凝結 / 溢出如何影響結果
- Why we need a control without turning on the immersion heater  
為什麼我們需要實驗控制組，例如：不打開浸入式加熱器

【More in 更多內容：中五考試 Heat By Topics - MCQ 1.3】

### 3. State the difference between "Evaporation" & "Boiling"

說明 " 蒸發 " 和 " 沸騰 " 之間的區別

Ans 答案：

#### Evaporation 蒸發

- is the process of vaporization of a liquid at room temperature.  
是室溫下液體汽化的過程。
- takes place at any given temperature.  
在任何給定溫度下發生。
- takes place mainly at the surface of the liquid.  
主要發生在液體表面。
- When evaporation takes place, the temperature of the liquid body decreases.  
發生蒸發時，液體溫度降低。



## Change of State 狀態變化

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### Boiling 沸騰

- is the process of evaporation of a liquid at the boiling point of the liquid.  
是在液體沸點蒸發液體的過程。
- takes place only at the boiling point of the liquid,  
僅在液體的沸點發生，
- takes place throughout the entire liquid.  
發生在整個液體中。
- The temperature remains constant throughout the boiling process.  
在整個沸騰過程中溫度保持恆定。

4. State the factors that affect the rate of evaporation of water:  
說明影響水蒸發速率的因素：

Ans 答案：

- Temperature 溫度
- Surface area 表面積
- Humidity 濕度
- Air pressure 空氣壓力
- Wind 風

5. Explain evaporation in terms of molecular motion.  
從分子運動的角度解釋蒸發。

Ans 答案：

- When the water molecules are moving randomly and colliding each other, some water molecules near the surface may acquire high enough kinetic energy to escape from the water surface. Since the water molecules with higher kinetic energy are escaped, the average K.E of the remaining water molecules will decrease and thus the temperature of water decreases.  
當水分子隨機運動並相互碰撞時，表面附近的一些水分子可能會獲得足夠高的動能以從水表面逸出。並且，由於具有較高動能的水分子被逸出，因此剩餘水分子的平均動能將降低，因此水的溫度降低。

## 4. Transfer Processes

### 傳熱方式

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#### "Must-understand" concepts

#### "必須理解" 的概念

The 3 ways of heat transfer 3 種傳熱方式：

- Conduction = heat transfer from hot body to cold body  
導熱 = 從較熱的物體到較冷的物體的熱傳遞
  - Heat conductors vs Heat insulators  
導熱體 vs 隔熱體
  - Solid with packed molecules & Metals with free electrons can generally conduct heat better.  
分子堆積密的固體和有自由電子的金屬可以更好地傳導熱量。
  - Vacuum, water and air are poor heat conductors  
真空，水和空氣是不良的熱導體
- Convection = heat transfer by the movement of fluid  
對流 = 流體運動的熱傳遞
  - When the fluid (gas / liquid) is heated, it becomes less dense and rises.  
當流體（氣體 / 液體）被加熱時，其密度減小並上升。
  - The colder fluid with higher density will sink down to replace the heated fluid.  
具有較高密度的較冷流體將沉沒下來以代替加熱流體。
  - E.g. Sea breezes – due to convection  
例如：海風 – 由於對流

## Transfer Processes 傳熱方式

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- Radiation = heat transfer by radiation, which doesn't require any medium.  
輻射 = 輻射傳熱，不需要任何介質
- Every object is emitting infrared radiations, except the one in 0K (absolute zero).  
除了 0 K ( 絕對零度 ) 之外，每一個物件都在發射紅外輻射。
- Infrared radiation can transfer heat and make you feel warm.  
紅外輻射可以傳遞熱量，使您感到溫暖。
- Dull black = good emitter and absorber of radiation  
暗黑色 = 良好的輻射發射器和吸收器
- Shiny white (e.g. silver) = poor emitter and absorber of radiation  
亮白色 (例如：銀) = 較差的輻射 器和吸收器

### "Should understand" concepts

#### " 應該理解 " 的概念

- The examples for illustrating Conduction, Convection, Radiation  
用於說明導熱，對流，輻射的示例
- Good conductors: Metals, Oil ...  
良好導熱體：金屬，油 ...
- Good insulators: Feathers, air, plastic, glass ...  
良好隔熱體：羽毛，空氣，塑料，玻璃 ...
- Convection: Air-conditioner, heater ...  
對流：空調，加熱器 ...
- Radiation emission: Spacecraft ...  
輻射發射：航天器 ...
- Radiation absorption: Solar cells ...  
輻射吸收：太陽能電池 ...

### "Must know" questions

#### " 必須知道 " 的問題

1. Describe the molecular motion during heat transfer by conduction.

描述在熱傳導過程中的分子運動。

Ans 答案：

Conduction is the process by which heat energy is transmitted through collisions between neighboring atoms or molecules. Heat by conduction causes molecules in the object to vibrate faster, making it hotter. These vibrating molecules collide with their neighboring molecules, making them also vibrate faster. As these molecules collide, thermal energy is transferred via conduction to the rest of the whole object.

傳導是熱能通過相鄰原子或分子之間的碰撞傳遞的過程。傳導熱會使物體中的分子振動得更快，從而使其變得更熱。這些振動分子與相鄰分子發生碰撞，從而使其振動也更快。當這些分子碰撞時，熱能通過傳導傳遞到整個物體的其餘部分。

2. Explain sea breeze with convection.

用對流解釋海風。

Ans 答案：

During daytime, the sun warms the ground and the sea. The ground has a lower specific heat capacity and so its temperature increases faster than the temperature of the sea. The ground heats the air above it, the air expands and rises, then cooler air from over the ocean flows toward to "fill in the gap". This flow of cooler air from the ocean toward the shore creates what is known as a sea breeze.

白天，陽光加熱地面和海洋。地面的比熱容較低，因此其溫度升高的速度比海洋溫度高。地面加熱上方的空氣，空氣膨脹並上升，然後冷空氣從海洋流向地面以 " 填補空隙 "。從海洋流向海岸地面的冷空氣形成了所謂的海風。

At night, the ground cools faster than the sea. The air over the sea is warmer than the air over the shore, and the reverse takes place. The warmer ocean air rises while a breeze flows from the shore to the sea.

到了晚上，地面降溫的速度比海洋要快。海洋的空氣要比岸上的空氣要熱，反之亦然，一陣微風從岸邊流向大海，海洋溫暖的空氣升起。

### 3. How does a vacuum flask work?

保溫瓶如何運作？

Ans 答案：

A vacuum flask can reduce heat transfer by:

保溫瓶可以通過以下方式減少熱傳遞：

- The glass walls reduce heat entering or leaving the flask by conduction.  
玻璃壁減少了通過傳導進入或離開燒瓶的熱量。
- The vacuum between the double walls prevents heat transfer by convection.  
雙壁之間的真空可防止對流傳熱。
- The silver coating on the inner walls reduces heat transfer by radiation.  
內壁上的銀塗層減少了輻射的熱傳遞。