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25 Questions To Power Up Temperature and Heat

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25 QUESTIONS TO POWER UP TEMPERATURE AND HEAT

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PREFACE

Heat and temperature are such closely related topics that the difference between the two can be quite confusing. The core difference is that heat is concerned with thermal energy, while temperature is more concerned with the kinetic energy of molecules. Heat is the transfer of thermal energy, while temperature is a property exhibited by an object.

This topic is very useful as a complement to all levels of learning, especially for first semester students at the polytechnic.

These concepts and theories are presented in a simple form. Appropriate and easy to follow to facilitate concepts and calculations.

The editors would like to express their utmost appreciation and gratitude to all the lecturers involved in the preparation of the module. Any positive feedback from any lecturer and student is most welcome and appreciated. It is our hope that this e-book will be the first step on a long journey to excellence.

Editor
Nur Elyani Musa
Azlina Hassan
Mohamad Zhahir Mohamed Zulkufli

PREFACE

JABATAN MATEMATIK SAINS DAN KOMPUTER

TABLE OF CONTENTS

Preface iii
Content iv
References v

CONTENTS PAGE

Lesson 1

1.1 Temperature 1
Definition, symbols & SI Units 1
1.2 Temperature Conversion Formula 1
How to convert 2
1.3 Heat 4
Definition, symbols & SI Units 4
1.4 Process of Heat Transfer 5
1.5 Specific Heat Capacity 7
1.6 Solving problems involving Specific Heat Capacity 9

Lesson 2

2.1 Thermal Equilibrium 14
Definition 14
2.2 Formula of Thermal Equilibrium 14
2.3 Solving problems involving Thermal Equilibrium 15

Lesson 3

3.1 Latent Heat 29
Definition, symbols & SI Units 29
Latent head absorbed vs Latent head released 29
3.2 Diagram of phase change of liquid 29
3.3 Type of Latent Heat 30
3.4 Specific Latent Heat 30
Definition, symbols & SI Units 30
Specific Latent Heat Fusion vs Specific Latent Heat Vaporization 30
3.5 Solving problems involving Specific Latent Heat 32

CONTENTS

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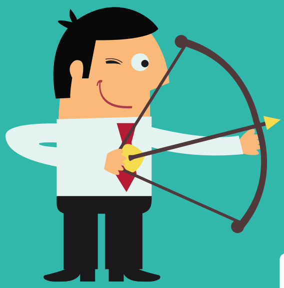


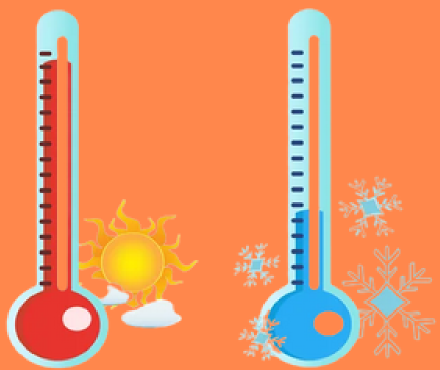
What will you learn in this subtopic?

- Temperature
- Heat
- Specific Heat Capacity
- Solving problems involving specific heat capacity

1.1 Temperature

Definition & Symbol

1. Temperature can be defined as the degree of hotness of an object.
2. It symbol is T.
3. Temperature is physical quantity that can be conveniently measured by using thermometer.
4. A hot object is at a higher temperature than a cold object.

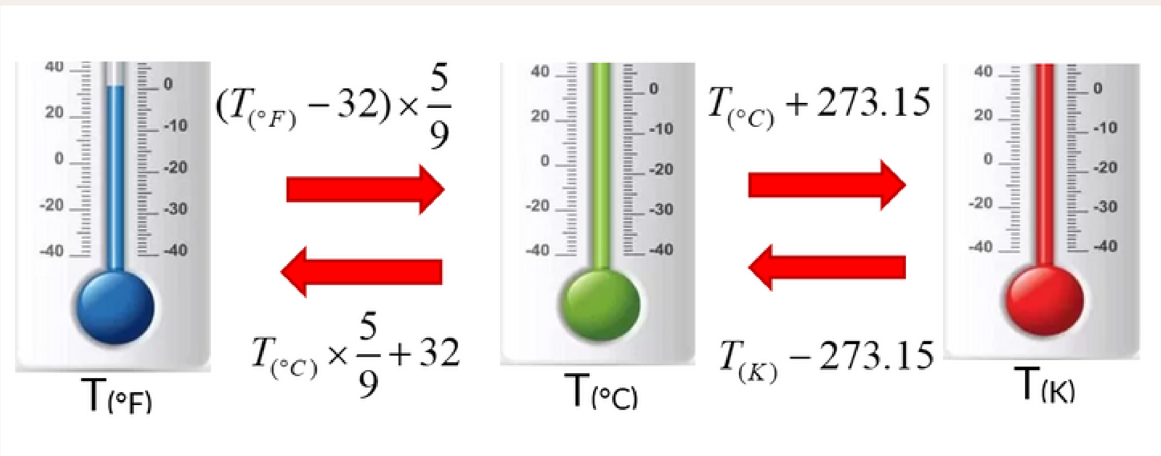


SI unit

Kelvin (K)

1.2 Temperature Conversion Formula

Fahrenheit → Celsius → Kelvin



How to convert

Celsius, ^0C ↔ Fahrenheit, ^0F

Example 1:

Convert 100 ^oC to Fahrenheit.

$$T_F = \frac{9}{5}(T_C) + 32$$

$$T_F = \frac{9}{5}(100) + 32$$

$$T_F = 212^oF$$

^0C → ^0F

$$T_F = \frac{9}{5}T_C + 32$$

Example 2:

Convert 302 ^oF to Celsius.

$$T_C = \frac{5}{9}(T_F - 32)$$

$$T_C = \frac{5}{9}(302 - 32)$$

$$T_C = 150^oC$$

^0F → ^0C

$$T_C = \frac{5}{9}(T_F - 32)$$

How to convert

Celsius, ^0C ↔ Kelvin, K

Example 3:

Convert 27 ^oC to Kelvin.

$$T_K = T_C + 273.15$$
$$T_K = 27 + 273.15$$
$$T_K = 300.15K$$

^0C → K

$T_K = T_C + 273.15$

Example 4:

Convert 270.15 *K* to Celsius.

$$T_C = T_K - 273.15$$
$$T_C = 270.15 - 273.15$$
$$T_C = 270.15 - 273.15$$
$$T_C = -3.15\,^0C$$

K → ^0C

$T_C = T_K - 273.15$

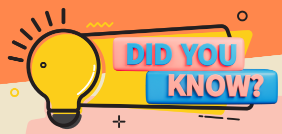
1.3 Heat

Definition & Symbol

1. Heat can be defined as the amount of thermal energy that flows naturally from hot body to cold body.
2. Symbol of heat is Q.

SI unit

Joule, J



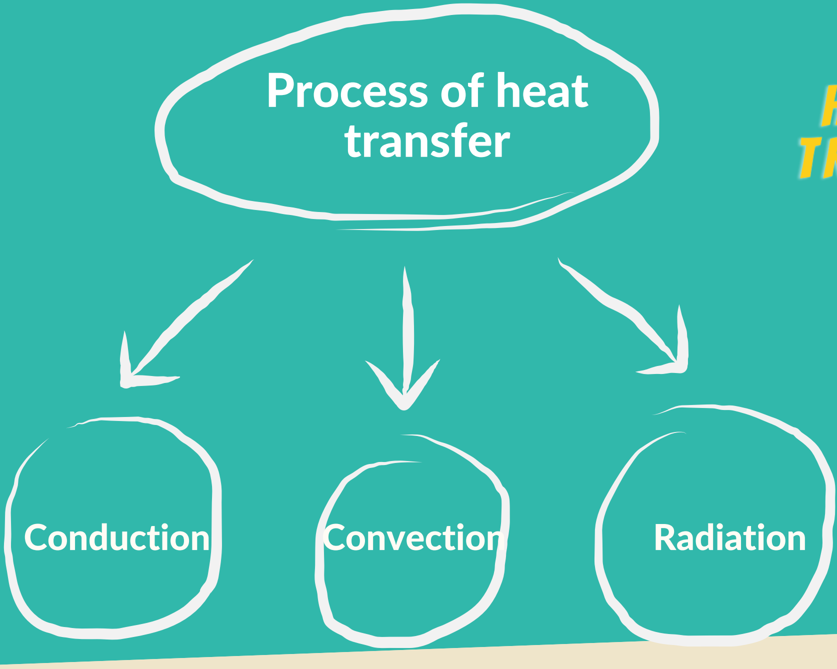
Heat and temperature are not the SAME thing.

Heat  Temperature

Table 1: Difference between Heat and Temperature

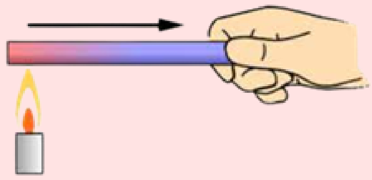
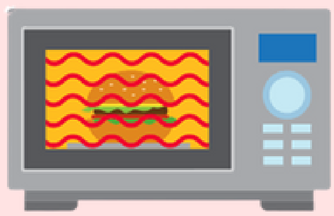
Criteria	Heat	Temperature
Definition	The amount of thermal energy that flows naturally from hot body to cold body.	The degree of hotness of an object.
Unit of Measurement	Joule, J	Kelvin (K)
Property	Flows from hot area to colder area	• Increases when heated. • Decreases when cooled.
Measuring equipment	No specific equipment	Thermometer

1.4 Process of Heat Transfer



HOW HEAT IS TRANSFERRED?

Table 2: Three ways of heat transfer

Type	Characteristic
Conduction	Transfer of heat between substances that are in direct contact with each other. Example: Heating the steel plate 
Convection	Up and down movement of gases and liquids caused by heat transfer. Example : Boiling a water 
Radiation	Transfer of heat when electromagnetic waves travel through space. Example : Microwave oven 

The formula of heat quantity,Q, due the temperature change is;

$$Q = mc\theta$$

where:

m = mass, kg

c = Specific Heat Capacity, J/kg °C

θ = Temperature Change, °C

"Success is the sum of small efforts, repeated."

-R Collier

1.5 Specific Heat Capacity, c

Definition & Symbol

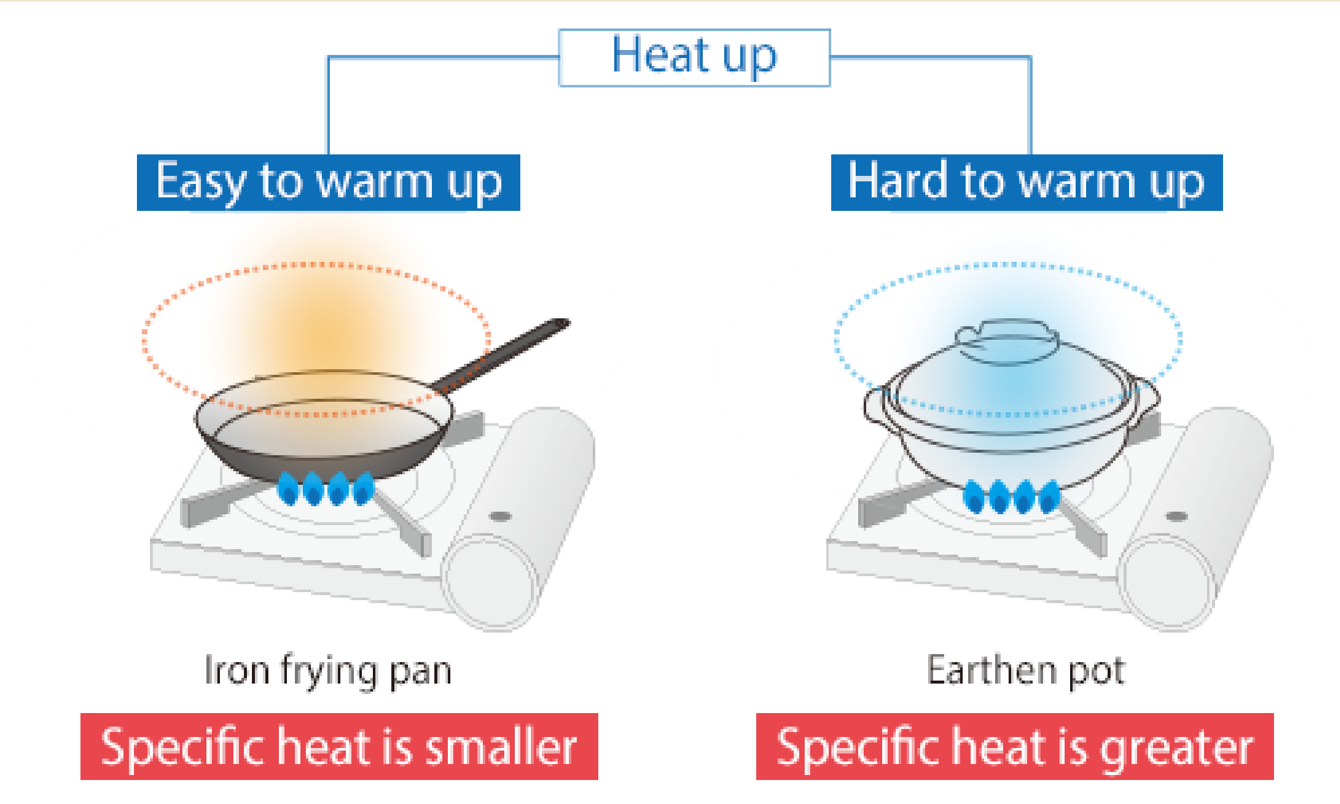
1. Specific heat capacity is the quantity of heat energy is required to increase the temperature of kilogram of substance by 1 degree Celsius or 1 Kelvin.
2. Symbol of specific heat capacity is c.

SI unit

$J/kg\,^{0}C$ @ $Jkg^{-1}\,^{0}C^{-1}$

DID YOU KNOW?

- **Metals have a low specific heat capacity**
- **Water has a high specific heat capacity**



The specific heat capacity, c, can be expressed by formula;

$$c = \frac{Q}{m\theta}$$

where:

c = Specific Heat Capacity, J/kg $^{\circ}$C

Q = Heat, J

m = mass, kg

θ = Temperature Change, $^{\circ}$C

"Success is the sum of small efforts, repeated."

-R Collier

1.6 Solving problems involving Specific Heat Capacity

EXAMPLE 1

Calculate the heat quantity to raise the temperature of 7 kg of water as much as $30^{o}C$.

Specific heat of water is $400 \ J/kg^{\circ}C$.

Step 1: List down information

m = 7 kg

θ = 30 ^{0}C

c = $400 \ J/kg^{\circ}C$

Step 2: Apply formula

$$Q = mc\theta$$

$$Q = 7kg \times 4200 \ (30^{\circ}C)$$

$$Q = 882000J$$

EXERCISE 1

Calculate the heat quantity needed to raise a temperature of 6 kg metal from $24°C$ to $36°C$. Given that that specific heat of metal is $380\ J/kg°C$.

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 2

How much heat energy is required to raise the temperature of 4 kg iron bar from $32°C$ to $52°C$. Specific heat of iron is $452 J/kg°C$.

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 3

8200 J of energy is required to raise the temperature of aluminium from $15°C$ to $52°C$. Calculate the mass of aluminium. (Specific heat of aluminium is $900 J / kg°C$).

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 4

Heat energy of 50000 J is needed to raise temperature of 2.5 kg metal block from $20°C$ to $70°C$. What is the specific heat capacity of the metal blocks?

Step 1: List down information

Step 2: Apply formula

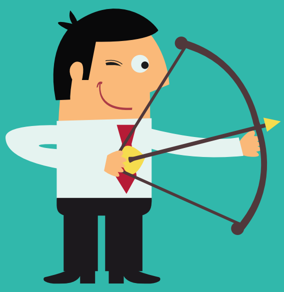
EXERCISE 5

A 3600 J of heat is needed to raise the temperature of 440 g of silver from $10°C$ to $45°C$. What is specific heat capacity of silver?

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER



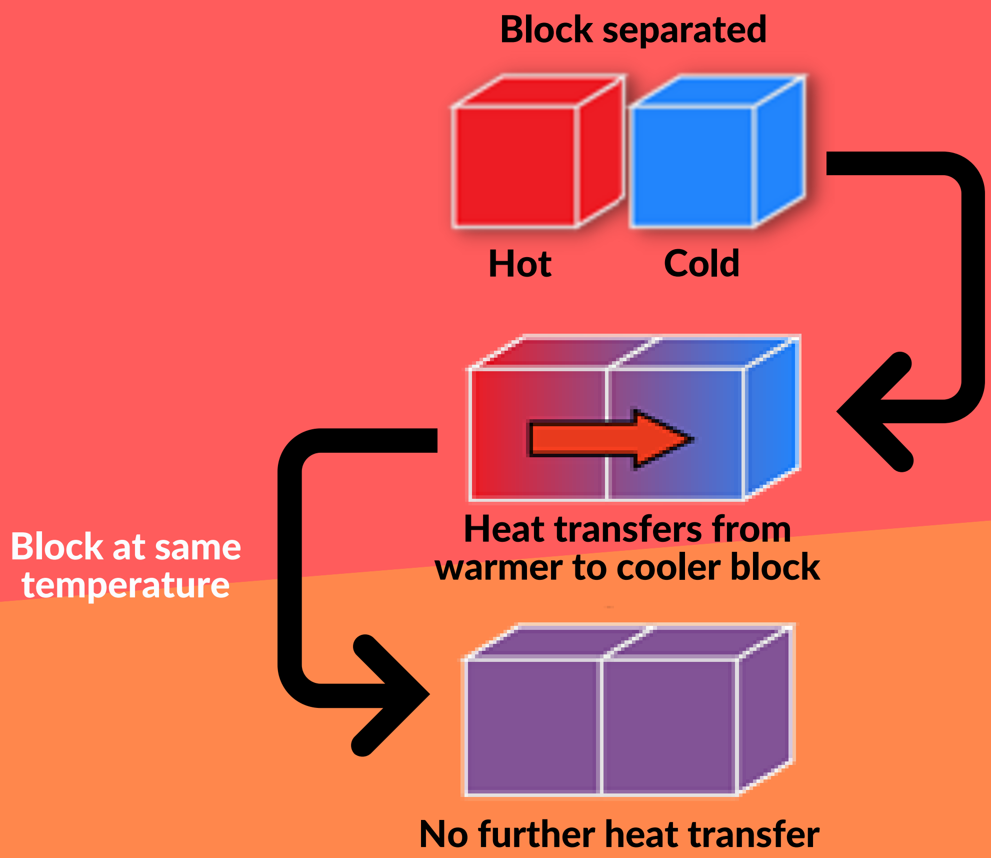
What will you learn in this subtopic?

- Thermal Equilibrium

2.1 Thermal Equilibrium

Definition

Thermal equilibrium is a condition where two objects in thermal contact have no net transfer of heat energy between each other until the objects have the same temperature.



Block in contact

- *When two objects with different degrees of hotness come into thermal contact, heat energy is transferred between two object.*

- *Process of heat transferred continues until the temperature of two bodies are equal.*
- *The equal temperature is called TFinal @ Tmixed*

2.2 Formula of Thermal Equilibrium

IMPORTANT!

$$Q_{loss} = Q_{absorb}$$

$$Q_{hot} = Q_{cold}$$

$$m_{hot} \times c_{hot} \times (T_{hot} - T_{final}) = m_{cold} \times c_{cold} \times (T_{final} - T_{cold})$$

2.3 Solving problems involving Thermal Equilibrium

EXAMPLE 2

200 g of hot water at temperature $80^{\circ}C$ is mixed up with 300 g of cold water at $20^{\circ}C$. Determine the final temperature of the mixture. (Specific heat capacity of water $4200 \ J/kg\ ^{o}C$)

Step 1: List down information

Quantity	Material	
	Hot water	Cold water
Mass, m	$\frac{200}{1000} = 0.2\ kg$	$\frac{300}{1000} = 0.3\ kg$
Specific Heat Capacity, c (J/kg ^{0}C)	4200	4200
Initial Temperature	80 ^{o}C (hot)	20 ^{o}C (cold)
Final Temperature, T_{final}	?	

Step 2: Apply formula

$$Q_{loss} = Q_{absorb}$$

$$Q_{hot} = Q_{cold}$$

$$m_{hot} \times c_{hot} \times (T_{hot} - T_{final}) = m_{cold} \times c_{cold} \times (T_{final} - T_{cold})$$

$$0.2 \times 4200 \times (80^{\circ}C - T_{final}) = 0.30 \times 4200 \times (T_{final} - 20^{\circ}C)$$

$$840\ (80^{\circ}C - T_{final}) = 1260\ (T_{final} - 20^{\circ}C)$$

$$67200 - 840\ T_{final} = 1260\ T_{final} - 25200$$

$$67200 + 25200 = 1260\ T_{final} + 840\ T_{final}$$

$$92400 = 2100\ T_{final}$$

$$T_{final} = \frac{92400}{2100}$$

$$T_{final} = 44\ ^{o}C$$

EXERCISE 6

Given that 450 g of water at $26^{\circ}C$ is added to 250 g of water at $100^{\circ}C$. Determine the final temperature of mixture.
(Specific heat capacity of water is $4200 \ J/kg^{\circ}C$)

Step 1: List down information

Quantity	Material	
	Hot water	Cold water
Mass, m		
Specific Heat Capacity, c ($J/kg\,^{o}C$)		
Initial Temperature		
Final Temperature, T_{final}		

Step 2: Apply formula

EXERCISE 7

A 0.25 kg of copper with an initial temperature of $99^{\circ}C$ is placed in an insulated container with 1 kg of water. The water has an initial temperature of $21^{\circ}C$. When the container is sealed, the copper and the water will eventually reach thermal equilibrium. What is the final temperature of the copper and water when they reach thermal equilibrium? (Specific heat capacity of Copper is $387 \quad J/kg^{\circ}C$ and specific heat capacity of water is $4200 \quad J/kg^{\circ}C$)

Step 1: List down information

Quantity	Material	
	Copper	Water
Mass, m		
Specific Heat Capacity, c ($J/kg\,^{o}C$)		
Initial Temperature		
Final Temperature, T_{final}		

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 8

If 2.15 kg of Zinc at $25^\circ C$ is mixed with 0.7 kg of water at $90^\circ C$. Find the final temperature of the mixture?

(Specific heat capacity of Zinc is $390 \ J/kg^\circ C$ and specific heat capacity of water is $4200 \ J/kg^\circ C$).

Step 1: List down information

Step 2: Apply formula

EXERCISE 9

A 25 g of aluminum is $85^{\circ}C$. Then, it is placed in the beaker that contains 55 g of water at $45^{\circ}C$. What is the final temperature of the water? (Specific heat capacity of aluminium is $900 \ J/kg^{o}C$ and specific heat capacity of water is $4200 \ J/kg^{o}C$).

Step 1: List down information

Step 2: Apply formula

EXERCISE 10

A 112 g of gold at $78^{\circ}C$ is immersed in 140 g of water at $27^{\circ}C$. Find the final temperature of the mixture?

(Specific heat capacity of gold is $129 \ J/kg^{\circ}C$ and specific heat capacity of water is $4200 \ J/kg^{\circ}C$).

Step 1: List down information

Step 2: Apply formula

EXERCISE 11

A 350 g block of iron at $82^{\circ}C$ is immersed in 225 g of water at $28^{\circ}C$. Find the final temperature assuming the system is isolated and the heat capacity of the cup can be neglected.

(Specific heat capacity of Iron is $452\ \ J/kg^{\circ}C$ and specific heat capacity of water is $4200\ \ J/kg^{\circ}C$).

Step 1: List down information

Step 2: Apply formula

PDF SUBMIT ANSWER

EXERCISE 12

A lecturer drinks her orange juice using an aluminium cup with a mass of 150 g at $25^{\circ}C$. If she pours 170 g of orange juice at $75^{\circ}C$ into the aluminium cup, calculate the final temperature after the orange juice and the aluminium cup attain thermal equilibrium?

(Specific heat capacity of Aluminium is $910 \ J/kg^{\circ}C$ and specific heat capacity of orange juice is $1730 \ J/kg^{\circ}C$).

Step 1: List down information

Step 2: Apply formula

PDF SUBMIT ANSWER

EXERCISE 13

A lecturer drinks her orange juice using an aluminium cup with a mass of 150 g at $25^{o}C$. If she pours 170 g of orange juice at $75^{o}C$ into the aluminium cup, calculate the final temperature after the orange juice and the aluminium cup attain thermal equilibrium?

(Specific heat capacity of Aluminium is $910 \ J/kg^{o}C$ and specific heat capacity of orange juice is $1730 \ J/kg^{o}C$).

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

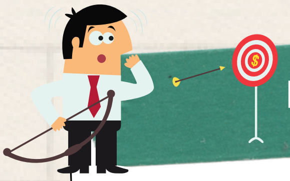
EXERCISE 14

A metal block 120 g is being heated to $115^{\circ}C$. Then, it being put into a 300 g of water with temperature of $28^{\circ}C$. Calculate the final temperature of the metal block and water. (Specific heat capacity of water is $4200 \ J/kg^{\circ}C$ and specific heat capacity of metal is $450 \ J/kg^{\circ}C$).

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER



EXERCISE 15

A 7 kg of metal cube at $60^{o}C$ is immersed in 3 kg water at $30^{o}C$.
If the final temperature of the water and the metal cube is $40^{o}C$.
What is the specific heat capacity of the metal?
(Specific heat capacity of water is $4200 \quad J/kg^{o}C$)

Step 1: List down information

Step 2: Apply formula

EXERCISE 16

4000 g of a silver spoon at temperature of $30^{o}C$ is being used to stir a glass of coffee at $80^{o}C$. It then reaches temperature of $60^{o}C$. If the specific heat capacity of silver is $470\ J/kg^{o}C$) and mass of coffee is 705 g, calculate specific heat capacity of coffee.

Step 1: List down information

Step 2: Apply formula

PDF SUBMIT ANSWER

EXERCISE 17

A piece of stone of mass 600 g at $26^{o}C$ is placed in a beaker containing 1.2 kg of water at $48^{o}C$. If the temperature of the water drops to $46^{o}C$, calculate the specific heat capacity of the stone.
(Specific heat capacity of water $4200 \ J/kg^{o}C$)

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 18

A 50 g piece of metal at $95^{\circ}C$ is dropped into 250 g of water at $17^{\circ}C$ and warms it to $19.4^{\circ}C$ What is the specific heat of metal.

(Specific heat capacity of water $4200 \quad J/kg^{\circ}C$)

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

What will you learn in this subtopic?

- Definition of Latent Heat
- Types of Latent Heat
- Definition of Specific Latent Heat, L
- Solving problems involving specific latent heat

3.1 Latent Heat

Definition & Symbol

Latent heat is the heat absorbed or released at a constant temperature during a change of phase of a matter. Symbol of latent heat is Q.

SI unit

Joule (J)

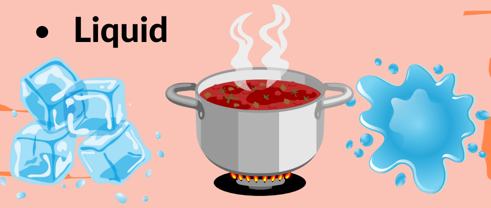
Latent heat absorbed vs Latent heat released

1. Latent heat absorbed is when a solid changes to a liquid or a solid changes to a gas.
2. Latent heat released is when gas changes to a liquid or liquid changes to a solid

DID YOU KNOW?

There are 3 phases of matter:

- **Solid**
- **Gas**
- **Liquid**



3.2 Diagram of phase change of liquid

To comprehend the idea of latent heat absorbed and latent heat released, look at Figure 6.1.

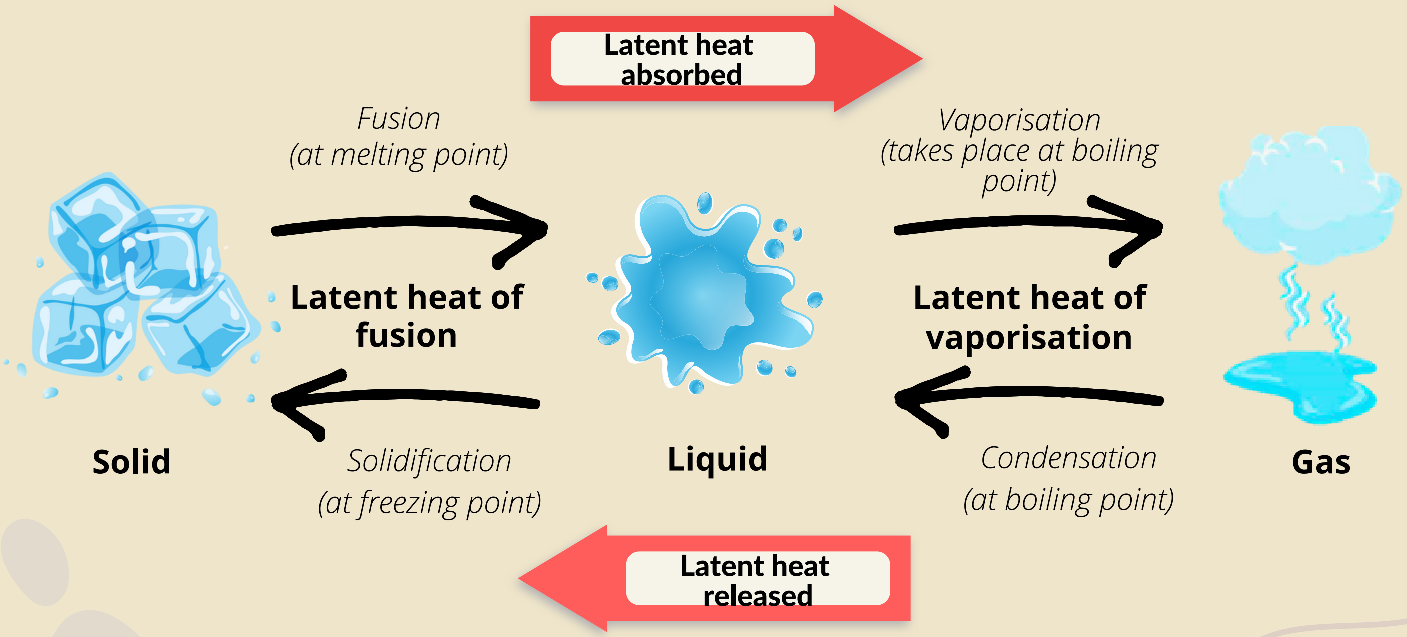


Figure 6.1: Diagram of phase change of liquid

3.3 Type of Latent Heat

There are TWO (2) types of latent heat which are latent heat of fusion and latent heat of vaporization.

Type of Latent Heat

Latent heat of fusion

Is the latent heat that is required to change of phase from solid to liquid (or liquid to solid) without any change in temperature.

Latent heat of vaporization

Is the latent heat that is required to change of phase from liquid to gas (or gas to liquid) without any change in temperature.

3.4 Specific Latent Heat

Definition & Symbol

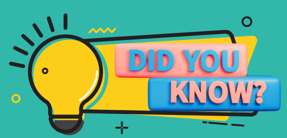
1. Specific latent heat is defined as the amount of heat energy required to change the phase of 1 kg of the substances at a constant temperature.
2. Symbol of specific latent heat is L.

SI unit

Joule per kilogram (J/kg @ Jkg^{-1})

Specific latent heat fusion vs Specific latent heat vaporization

1. Specific latent heat of fusion = the change from solid to liquid.
2. Specific latent heat of vaporization = the change from liquid to gas.



There is one key difference between Specific Heat Capacity and Specific Latent Heat

Specific heat capacity	Specific latent heat
Amount of heat energy needed to change one kilogram of a material by 1°C. *(change of temperature)*	Amount of heat energy needed to change the phase (gas, liquid, solid) of one kilogram of material. *(change of phase)*

Specific latent heat of fusion or vaporization, L can be expressed as:

$$L = \frac{Q}{m}$$

where:

Q = Latent heat absorbed or released (J)

m = mass (kg)

L = specific latent heat of fusion or vaporization (J/kg)

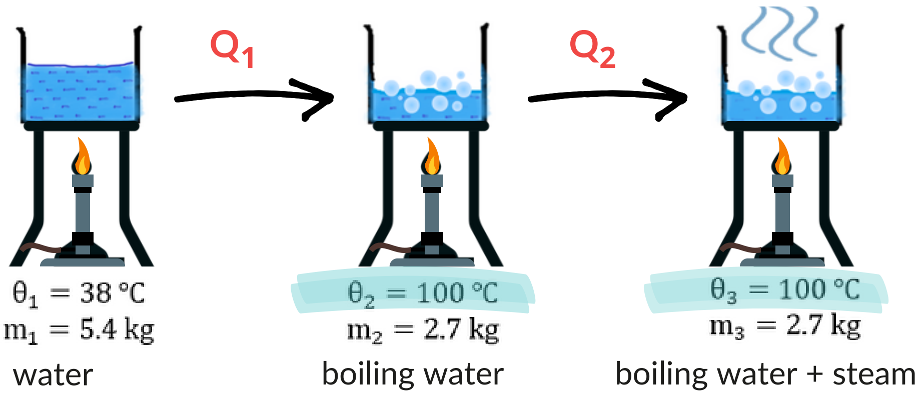
"Success is the sum of small efforts, repeated."

-R Collier

3.5 Solving problems involving specific latent heat

EXAMPLE 3

5.4 kg of water at 38 °C is heated until half of it is changes to steam at 100 °C. Determine the heat energy needs to be supplied to the water. Given specific heat capacity of water = 4200 $Jkg^{-1}\,^{o}C^{-1}$ and specific latent heat of vaporization = 2.26×10^6 J/kg °C.



Step 1: List down information

$m_1 = 5.4$ kg

$\theta_1 = 38\,^{o}C$

$m_2 = m_3 = 5.4$ kg / 2 = 2.7 kg

$\theta_2 = \theta_3 = 100\,^{o}C$

$c_{water} = 4200$ J/kg °C

$c_{vaporization} = 2.26 \times 10^6$ J/kg °C

$Q_{total} = ?$

TOP TIPS

Why does the temperature remain constant during boiling?
The temperature remains constant during boiling of water even though heat is supplied constantly because **all the heat energy provided is used up in changing the state of water from liquid to gaseous (steam).**

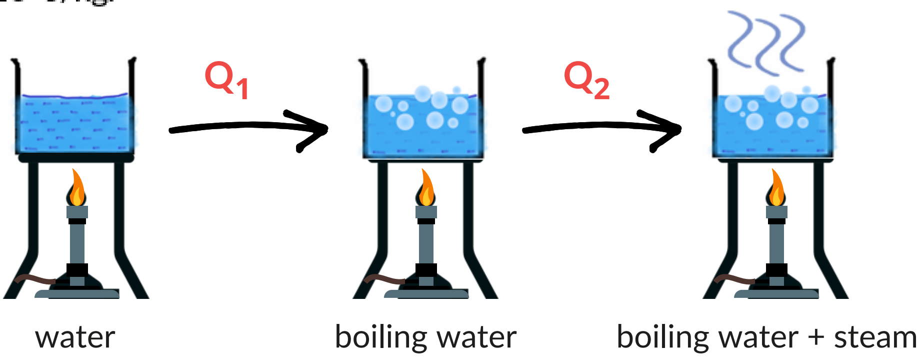
Step 2: Apply formula

To find Q_{Total}, you must find the amount of Q_1 and Q_2.

$$Q_1 = mc\theta$$
$$= 5.4(4200)(100 - 38)$$
$$= 1406160\,J$$
$$Q_2 = mL$$
$$= 2.7(2.26 \times 10^6)$$
$$= 6102000\,J$$
$$\therefore Q_{Total} = Q_1 + Q_2$$
$$= 1406160 + 6102000$$
$$= 7508160\,J$$

EXERCISE 19

500 g of water at 25 ^{0}C is heated until all of it is converted to steam. Calculate the amount of heat energy supplied to it if specific heat capacity of water is 4200 $Jkg^{-1}\,{}^{0}C^{-1}$ and specific latent heat of vaporization is 2.26×10^{6} J/kg.



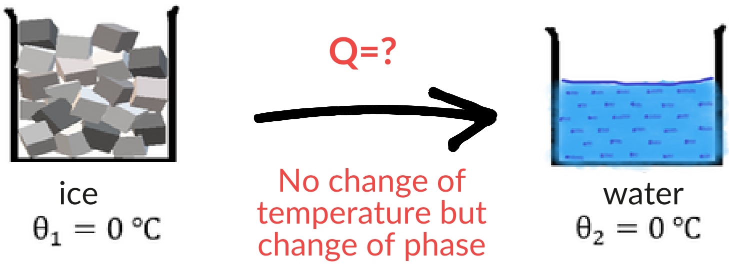
Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 20

Calculate the heat energy is needed to change 2.8 kg of ice at 0 ^{0}C to water at 0 ^{0}C. Given specific latent heat of fusion = 3.3×10^5 J/kg ^{0}C.



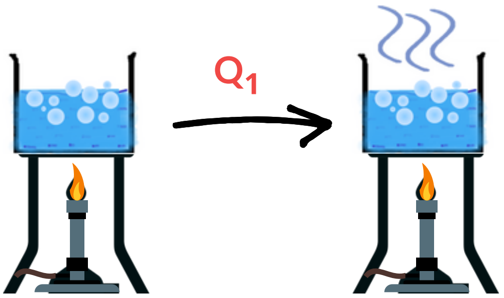
Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 21

How much heat energy is needed to change 250 g of water at 100 ^{0}C to steam at 100 ^{0}C. Given specific latent heat of fusion = 3.3×10^{5} J/kg ^{0}C.



boiling water   boiling water + steam

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 22

Determine the heat required for a refrigerator to change 1.5 kg of water at 20 ^{o}C to ice at 0 ^{o}C? Given specific latent heat of fusion = 3.3×10^{5} J/kg ^{o}C.

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 23

A group of students was provided with 75 kg of ice to convert to steam. If the initial temperature of ice is $-10\ ^{0}C$, calculate the heat required to change the ice to steam.

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 24

A student conducted an experiment to observe the change of phase of ice by heating 2.3 kg of ice at -5 ^{o}C. If the temperature of ice was reduced from -5 ^{o}C to water at 30 ^{o}C, determine the total heat supplied to it. Given specific heat capacity of ice = 2100 J/kg ^{o}C, specific heat capacity of water = 4200 J/kg ^{o}C and specific latent heat of fusion of ice = 336 000 J/kg ^{o}C.

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

EXERCISE 25

Ali keeps 2000 g of water of 70 ^{0}C in a refrigerator. After 8 hours later, he found that the water was freeze at -11 ^{0}C. Calculate the heat required by the refrigerator to freeze the water.

Step 1: List down information

Step 2: Apply formula

SUBMIT ANSWER

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