Delta Science Education

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HKDSE Physics

Core 1: Heat and Gases

Chapter 1: Temperature, Heat and Internal Energy

Part 2

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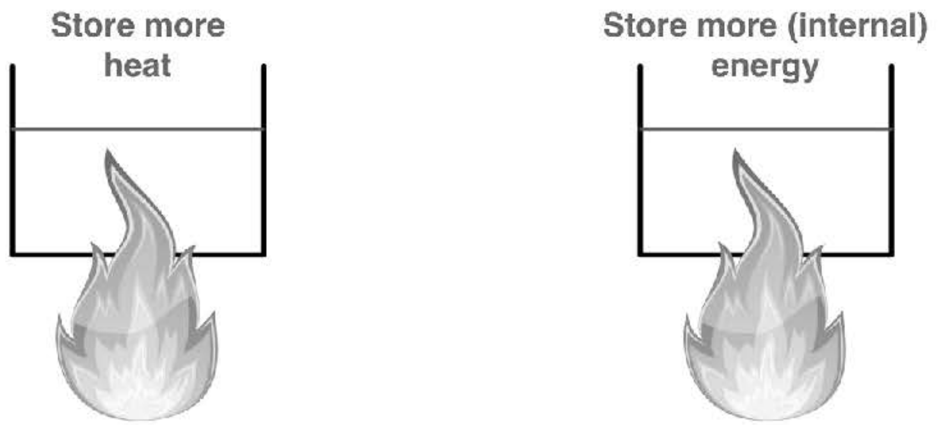
2. Heat and Internal Energy

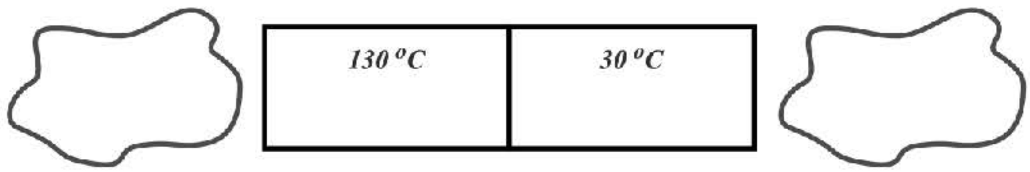
(1) Definition of heat, Q

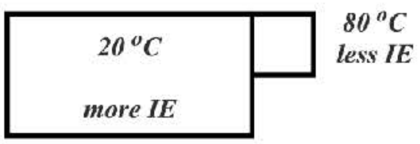
- **Heat** can be:
    - the **process to transfer energy** as a result of ______ between two bodies; and
    - (also called **heat flow / heat energy / thermal energy**) the amount of **energy transferred** due to the ______ between two bodies.
- Unit of heat (energy): **Joule (J)**

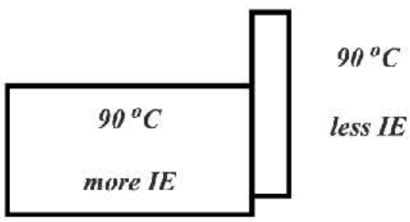


(2) Direction of heat flow

- **Heat always flows from ______ temperature region/object to ______ temperature region/object.**







- **No heat exchange between two bodies if they are at the same temperature (______).**

Examples that you must fully understand

1. Which of the following statements concerning heat is / are correct?

   (1) When the temperature of a body is increased, it stores more heat.

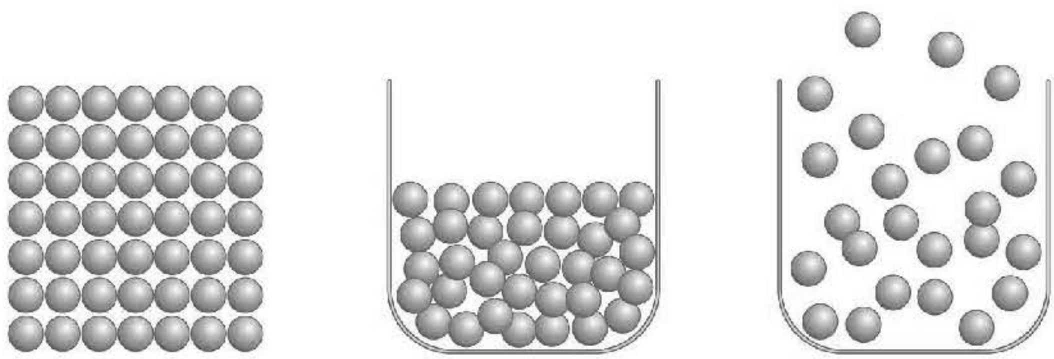
   (2) In a cup of water containing melting ice, there is no heat exchange between the ice and the water.

   (3) Heat must be transferred from a body with a greater amount of internal energy to a body with a lower amount of internal energy.

   (4) Two bodies in thermal equilibrium must store the same amount of internal energy.

(3) Definition of internal energy, *E*

■ According to the **Kinetic Theory**, all substances are composed of particles (molecules):



■ Internal energy is the total energy stored inside the material of a body. It consists of

•

•

■ Unit of internal energy: **Joule (J)**

■ **Factors** affecting the amount of internal energy in a body:

• ______ of the body

• ______ of the body

• ______ of the body

• ______ of the body

(4) Change of internal energy

- The internal energy of a body **can be altered** by

(i) heating – through <u>temperature difference</u>	(ii) doing work – through the application of a ☐
	

What will happen to an object after it is heated? It ☐ heat so its internal energy must ☐.	
Without change of state	**With change of state**
• **the average molecular PE:** • **its temperature and average molecular KE:**	• **its temperature and average molecular KE:** • **the average molecular PE:**

What will happen to an object after it is cooled? It ☐ heat so its internal energy must ☐.	
Without change of state	**With change of state**
• **the average molecular PE:** • **its temperature and average molecular KE:**	• **its temperature and average molecular KE:** • **the average molecular PE:**

Examples that you must fully understand

2. Which of the following statements about internal energy is / are true?

   (1) A copper block has a greater amount of internal energy when it is hot than when it is cold.

   (2) In a mixture of water and ice, the water has a greater amount of internal energy than the ice.

   (3) Different masses of water at the same temperature have the same amount of internal energy.

   (4) Two bodies of the same temperature must have the same internal energy.

   (5) When a body is at 0°C, it has no internal energy.

3. Which of the following statements concerning temperature is / are correct?

   (1) Temperature is a measure of the degree of hotness of an object.

   (2) Temperature is a measure of the average kinetic energy of the molecules of an object.

   (3) Temperature is a measure of the internal energy of an object.

4. Which of the following can represent the temperature of an object?

   (1) degree of hotness of the object

   (2) internal energy of the object

   (3) total kinetic energy of the molecules of the object

5. Which of the following statements is / are true?

   (1) Substance with higher temperature must have higher molecular KE.

   (2) Substance with higher temperature must have higher average molecular KE.

   (3) Substance with higher temperature must have higher internal energy.

   (4) Substance with higher temperature must have higher average molecular PE.

6. Which of the following statements about internal energy is / are true?

   (1) The average kinetic energy of water molecules in 2 kg of water is greater than that in 1 kg of water.

   (2) The total kinetic energy of water molecules in 2 kg of water is greater than that in 1 kg of water at the same temperature.

   (3) The average potential energy of water molecules in 2 kg of ice is less than that in 1 kg of water.

   (4) The total potential energy of water molecules in 2 kg of water is greater than that in 1 kg of water at the same temperature.

7. Which of the following statements about heat is / are true?

   (1) Heat is the total energy stored in a body.

   (2) Heat is the energy transferred from one body to another as a result of the temperature difference between them.

   (3) When a body is heated, its temperature must increase.

   (4) When a body is heated, its internal energy must increase.

   (5) The internal energy of a body can only be increased by heating.

Examples that you must fully understand

8. Which of the following statements is / are true?

   (1) When two objects are in contact, there must be heat transfer from the object with more internal energy to the one with less internal energy.

   (2) When two objects are in contact, there must be heat transfer from the object with higher temperature to the one with lower temperature.

   (3) When two objects are in contact, there must be heat transfer from the object with higher average molecular KE to the one with lower molecular KE.

   (4) An object with higher temperature must store more internal energy than another object with lower temperature.

   (5) The internal energy stored in an object increases with its temperature.

9. Which of the following statements concerning a body under heating is/are correct?

   (1) The internal energy of a body must increase after heating.

   (2) The KE of molecules of a body must increase after heating.

   (3) The PE of molecules of a body must increase after heating.

   (4) The KE and PE of molecules can be increased at the same time.

   (5) The temperature of a body must increase after heating.

   (6) The temperature of a gas must increase after heating.

   (7) The average PE of water at 100°C must increase after heating under normal atmospheric pressure.

10. When body A is in contact with body B, it is found that heat flows from A to B. Which of the following conclusions must be correct?

   (1) A heats B.

   (2) The internal energy stored in A is greater than that in B.

   (3) The temperature of A is greater than that of B.

   (4) The average molecular KE in A is greater than that in B.

   (5) Temperature of B increases.

   (6) The average molecular KE of B increases.

   (7) The average molecular PE of B increases.

   (8) The internal energy in B increases.

   (9) The internal energy in A decreases.

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11. Which of the following statements must be correct about cooling?

(1) When some gas is being cooled, its average molecular KE must decrease.

(2) When some liquid is being cooled, its average molecular PE must decrease.

(3) When some ice is being cooled, its average molecular KE must decrease.

(4) When some water vapour is being cooled, its internal energy must decrease.

12. Which of the following statements must be correct about cooling?

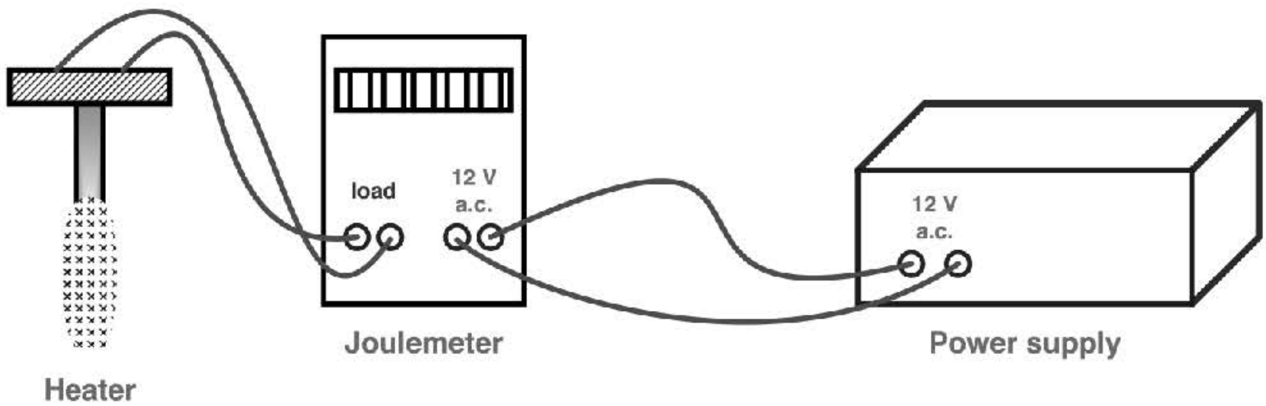
(1) When some gas is being heated, its average molecular KE must increase.

(2) When some liquid is being heated, its average molecular PE must increase.

(3) When some water vapour is being heated, its internal energy must increase.

(4) When some ice is being heated, its average molecular KE must increase.

(5) Measurement of energy transfer by a joulemeter



- A heater when connected to a power supply can give out heat **at a steady rate**.
- A **joulemeter** can measure the ______ given out by the heater.

3. Power

(1) Definition of power

- Power P is the rate of transfer of heat Q.

- Unit of power: **watt 1 W = 1 J s^{-1}**

	Kettle 1	Kettle 2
		
Power	2.5 kW	900 W
Energy supplied by the kettle in one second		
Energy supplied in one hour		
Time to heat 2 kg water from room temperature to boiling point (= 630,000 J of heat)		

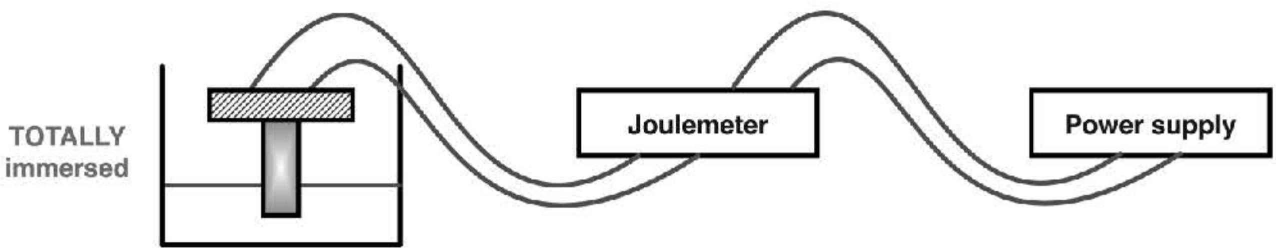
- A heater of greater power can give out ______ **in a certain period of time**.

- A heater of greater power can give out **a certain amount of energy** in a ______.

- A heater of greater power **will not change** the ______ **point** or ______ **point** of a substance.

Examples that you must fully understand
13. A cup of water is heated by an immersion heater. If the water absorbs 3.0×10^5 J in 50 minutes, what is the power of the heater.
14. A water-containing iron cup is heated up by a heater for 20 minutes. If the power of the heater is 500 W and the water absorbs 4.8×10^5 J energy, what is the heat absorbed by the iron cup?
15. A heater of power 200 W needs 5 minutes to heat a cup of water from room temperature to the boiling point. If another heater of power 400 W is used, how long does it take for the same process?

(2) Measurement of the power of a heater by a joulemeter



■ Procedure of measurement:

- *Connect a joulemeter to the heater from the power supply.*
- *Measure the initial reading and the final reading of the joulemeter.*
- *The difference of the two readings gives the heat Q supplied by the heater.*
- *Measure the time taken t by use of a stop-watch.*
- *The power of the heater is then found by* .

Examples that you must fully understand

16. A heater is totally immersed in water. It is then connected to a power supply via a joulemeter. The following data are recorded:

Initial joulemeter reading = 268,500 J

Final joulemeter reading = 493,500 J

Time taken by use of a stop-watch = 2.5 minutes

(a) Calculate the heat transferred *Q* by the heater. Hence find the power *P* of the heater.

(b) How much energy can be supplied by the heater in 2 hours?

(c) How long does it take to supply 45 kJ of energy?

(3) The unit of kilowatt-hour

- **Kilowatt-hour (kWh)** is another unit of ________.
- **1 kWh** is the energy given out by a **1 kW** heater in **1 hour**.
- A **kilowatt-hour meter** is used to measure the energy given out by a heater in **kWh**.

Examples that you must fully understand

17. A heater is connected to a power supply via a kilowatt-hour meter. A stopwatch is also used. The initial meter reading is 2.85 kWh. After 13 minutes 20 seconds, the meter reading becomes 3.25 kWh. Find the heat transferred, Q by the heater and determine the power of the heater.

4. Specific Heat Capacity

(1) Heat absorbed by a substance

- The **heat Q required to be absorbed** by a substance to increase its temperature is directly proportional to the **increase of temperature** ΔT for the **same mass** of the substance.
  - Taking **1 kg of water** as an example,

    Q to increase $1°C = 4,200$ J Q to increase $2°C = 8,400$ J Q to increase $10°C = 42,000$ J

- The **heat Q required to be absorbed** by a substance to increase its temperature is directly proportional to the **mass m** of the substance for the **same rise** in temperature.
  - Taking **water** as an example, we want to **increase the temperature by 10°C**,

    Q for 1 kg = 42,000 J Q for 2 kg = 84,000 J Q for 10 kg = 420,000 J

- However, for **two different substances** with the **same mass**, the heat required to give the **same rise of temperature** may not be the same:
  - Taking **1 kg water** and **1 kg of alcohol** as an example, to **increase the temperature by 1°C**,

    Q for 1 kg of water to increase $1°C = 4,200$ J

    Q for 1 kg of alcohol to increase $1°C = 2,400$ J

(2) Definition of the specific heat capacity c

- **The heat absorbed (or released) to increase (or decrease) a certain mass of a certain substance to a certain rise (or drop) in temperature** can then be calculated by:

- **Specific heat capacity** of a ________ is the heat required to raise the temperature of **1 kg** of the substance through **1°C**.

- Unit of c: **J kg^{-1} °C^{-1}** or **J kg^{-1} K^{-1}**

- Specific heat capacity for a substance is a constant that depends on the **material** and its **state**:

Substance	c	Substance	c	Substance	c
Water	4,200	**Ice**	2,100	**Steam**	2,010
Aluminium	900	**Gold**	129	**Iron**	448
Wood	1,700	**Glass**	837	**Alcohol**	2,400

- The specific heat capacity of a kind of substance **is** ☐ **affected** by factors including:
  - Mass
  - Temperature
  - Shape
  - Types of containers
  - Pressure

Examples that you must fully understand

18. Suppose you are given samples of iron, glass, and water, and all of the them are at 25°C. With reference to the table above,

    (a) if 1,000 J of heat is supplied to each of the samples separately, calculate the final temperature of samples and arrange the final temperatures in ascending order. You can assume there is no heat loss to the surroundings and the mass of each sample is 1 kg.

    (b) if the samples are now placed in a fridge at 4°C, calculate the amount of heat released by the samples upon reaching thermal equilibrium with the fridge and arrange the heat released in ascending order. The mass of each sample is now 2 kg.

(c) if the samples are now being heated by a heater of 250 W for 10 minutes. The temperature of the all the samples then increased to 69°C. Assume during the heating process, no heat is lost to the surroundings. Calculate the mass of the samples and arrange the masses in ascending order.

(d) if the samples are now being heated by a heater of 700 W. Assume during the heating process, 15% of the energy generated by the heater is lost to the surroundings. Calculate the time required to increase the temperature of each sample by 30°C and arrange the time in ascending order.

19. Which of the following pairs of objects have the same specific heat capacity?

(1) 1 kg of water and 2 kg of water

(2) 1 kg of ice and 1 kg of water

(3) 1 kg of water and 1 kg of alcohol

(4) 1 kg of water at 10°C and 1 kg of water 90°C.

(5) 1 kg of water in a copper container and 1 kg of water in a plastic container.

20. A 0.2 kg hot aluminium container is put into a refrigerator for half an hour. 45,000 J of energy is being removed from the container and the temperature drops from 200°C to –50°C. Calculate the specific heat capacity of the container.

Examples that you must fully understand

21. An equal amount of heat is supplied to each of the following substances and the rises in temperature are recorded.

Substance	**Mass (kg)**	**Rise in temperature (°C)**	
X	**2.0**	**7**	
Y	**2.5**	**6**	
Z	**3.0**	**4**	

Arrange the specific heat capacity of the above 3 substances in ascending order:

22. Eating a cup of ice cream can absorb about 80,000 J of heat from our bodies. Give a rough estimation of the body temperature drop for a person after he/she eats a cup of ice-cream. You can assume the person is made of water only and the mass is 50 kg.
(c of water = 4200 J kg^{-1} °C^{-1})

(3) Conservation of energy

- The energy supplied by a heater is equal to the energy gained by the ______ if **there is no heat lost to the surroundings.**

- The energy supplied by a heater is ______ to the energy gained by the substance if **there is heat loss to the surroundings.**

Examples that you must fully understand

23. A heater of power 1.2 kW supplies energy to a liquid of mass 2 kg. When the heater is switched on for 200 s, the temperature of the liquid rises from 25.6°C to 62.9°C. Assume no heat is lost to the surroundings.

(a) Find the energy supplied to the liquid by the heater.

(b) What is the temperature rise of the liquid?

(c) Find the specific heat capacity of the liquid.

24. A heater of 800 W has heated 0.4 kg of water for 100 s, the water temperature increased from 25°C to 70°C. Find the heat loss to the surroundings. (c of water = 4200 J kg^{-1} $°C^{-1}$)

25. A heater of power 250 W supplies energy to a liquid of mass 2.5 kg and specific heat capacity 3 500 J kg^{-1} $°C^{-1}$ contained in a vessel of negligible heat capacity. The initial temperature of the liquid is 15°C.
Assume that 20% of heat supplied is lost to the surrounding air and the apparatus. Find the heat Q gained by the liquid and determine the final temperature of the liquid after the heater has switched on for 7 minutes.

26. A heater supplies energy to a liquid of mass 0.5 kg and the specific heat capacity of the liquid is 4000 J kg^{-1} $°C^{-1}$. If the temperature of the liquid rises from 10°C to 70°C in 100 s, calculate the power of the heater. You can assume only 70% of the heat supplied by the heater is absorbed by the liquid.

(4) Heat capacity

- A **certain** ☐ **(a certain** ☐ **at a certain state)** has a **specific value of specific heat capacity**, c
  which is ☐ **of the actual mass of the body** since the **mass is assumed to be** 1 kg.

Substance	c (J kg^{-1} °C^{-1})	Substance	c (J kg^{-1} °C^{-1})	Substance	c (J kg^{-1} °C^{-1})
Water	4,200	**Ice**	2,100	**Steam**	2,010
Aluminium	900	**Gold**	129	**Iron**	448
Wood	1,700	**Glass**	837	**Alcohol**	2,400

- **Heat capacity** C of a specific substance ☐ depends on both the ☐ and the **actual** ☐ of the body or object:

Body	C (J °C^{-1})	Body	C (J °C^{-1})	Body	C (J °C^{-1})
1 kg Water	4,200	**2 kg Water**	8,400	**10 kg Water**	42,000
1 kg Al	900	**2 kg Al**	1,800	**10 kg Al**	9,000
1 kg Glass	837	**2 kg Glass**	1,674	**10 kg Glass**	8,370

- Thus, the relation between Heat capacity C and Specific heat capacity c is

☐

- Factors affecting the **heat capacity** of a body:
  - ***Material and the state of the object***
  - ***Mass of the object***

- Heat capacity C is the heat Q required to raise the temperature of a specific ☐ through **1°C.**

- Unit of heat capacity: **J °C^{-1}** or **J K^{-1}**

Examples that you must fully understand

27. A metal cup contains 250 g of water at 25°C. A heater of power 200 W is used to heat the water. After 12 minutes, the temperature of water reaches 70°C. Assume that the water and the metal cup are always at the same temperature and 20% of heat supplied by the heater is lost to the surrounding. You can take the specific heat capacity of water to be 4,200 J kg^{-1} $°C^{-1}$.

(a) Find the heat capacity of the metal cup.

(b) If the mass of the metal cup is 400 g, find the specific heat capacity of the metal.

(c) Find the time required to heat the water from 7°C to the boiling point.

28. Suppose an electric kettle is connected to the mains supply.

Mass of water in the kettle = 1.2 kg

Initial temperature of water in the kettle = 20°C

Specific heat capacity of water = 4 200 J kg^{-1} $°C^{-1}$

Heat capacity of the kettle = 600 J $°C^{-1}$

(a) Suppose the temperature of the water becomes 65°C after 2.5 minutes. By finding the heat gained by the kettle and the water, estimate the electrical power supplied to the kettle.

(b) State TWO major assumptions in your calculation.

Assume ______________ to the surrounding air.

Assume the kettle and the water have the ______________.

(c) How long does it take to further increase the temperature of water from 65°C to the boiling point?

Examples that you must fully understand

29. Which of the following can increase the specific heat capacity of a metal block?

(1) Increase the mass of the block.

(2) Increase the block's temperature.

(3) Change the shape of the block.

(4) Divide the block into smaller blocks.

30. Which of the following can increase the heat capacity of a metal block made of iron?

(1) Increase the mass of the block.

(2) Increase the block's temperature.

(3) Change the shape of the block.

(4) Divide the block into smaller blocks.

(5) Change the metal from iron to aluminium.

31. Two liquids A and B below are heated respectively. Which of the following statements are correct?

	Liquid A	Liquid B
Energy supplied / J	240,000	180,000
Mass / kg	0.4	0.2
Temperature rise / °C	20	25

(1) The heat capacity of A is larger than that of B.

(2) The specific heat capacity of A is larger than that of B.

(3) The heat capacity of A remains unchanged if the mass of A is doubled.

32. A cup X contains 0.9 kg of water while a cup Y contains 0.5 kg of water and both of them are kept at the same temperature. Which of the following statements is/are correct?

(1) The specific heat capacity of water in cup X is greater than that of the water in cup Y.

(2) The heat capacity of water in cup X is greater than that of water in cup Y.

(3) The internal energy of water in cup X is greater than that of water in cup Y.

(4) It requires more heat to increase the water in cup X by 10°C.

(5) When the cups are in contact, heat flows from cup X to cup Y.

33. There are two pools in a public swimming pool, i.e. a training pool and a main pool. It is noted that the training pool has a similar area with the main pool but the training pool's depth is only half of the main pool. If they are under the sunlight for the same period of time, guess which pool's water temperate has a faster rate of increase.

5. Specific Heat Capacity of Water

(1) High value of Specific Heat Capacity of water

- The specific capacity of water is exceptionally **high**, $c = 4{,}200 \text{ J kg}^{-1}\,{}^{\circ}\text{C}^{-1}$
- As a result, when compared with other material,
  - **water absorbs ______ for the same temperature rise;**
  - **water's rise in temperature is ______ for the same amount of heat absorbed.**

Examples that you must fully understand

34. The specific heat capacities of water and oil are $4200 \text{ J kg}^{-1}\,{}^{\circ}\text{C}^{-1}$ and $2100 \text{ J kg}^{-1}\,{}^{\circ}\text{C}^{-1}$ respectively. There are 1.5 kg of water and 1.5 kg of oil at 25°C.

(a) What are their rises in temperature if 126,000 J of energy is supplied to each of them?

(b) What is the energy needed respectively to rise their temperature to 75°C?

(c) Suppose both water and oil are heated to 75°C and they are left in room temperature. Which one do you think will drop back to the room temperature first? What is your assumption made?

______. Since the ______ of the ______ is ______ than that of the ______. Less heat has to be lost to have the same temperature drop (back to room temperature).

It is assumed that ______.

(d) Wrapping the liquids in part (c) with cotton wool makes them take a longer time to drop back to room temperature. John says that this is due to the fact that less heat is lost to the surroundings. Comment on his explanation.

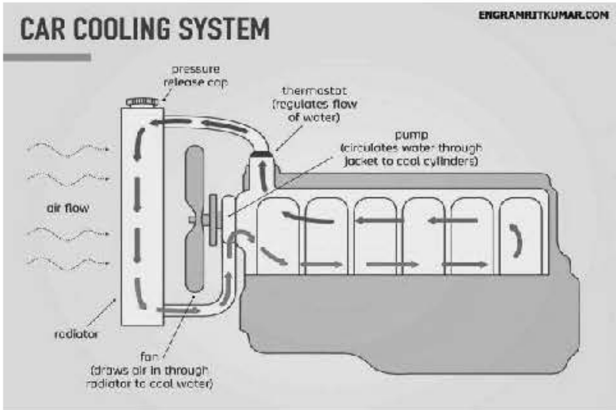
______. Even the liquids are wrapped with cotton wool, ______ ______ have the same temperature drop (back to room temperature).

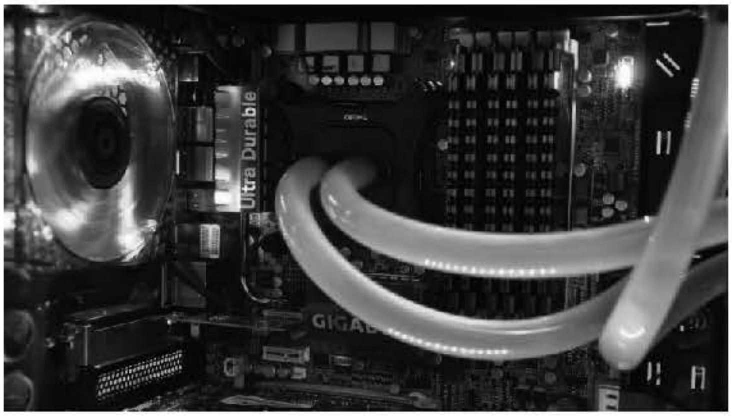
However, the ______, resulting in a longer time to drop back to the room temperature.

(2) Application of the high specific capacity

1. ***As a cooling agent***

   - Water is used as the coolant in many machines, including a car radiator, as it can absorb a large amount of heat without much rise in temperature.





2. ***Stabilizing body temperature***

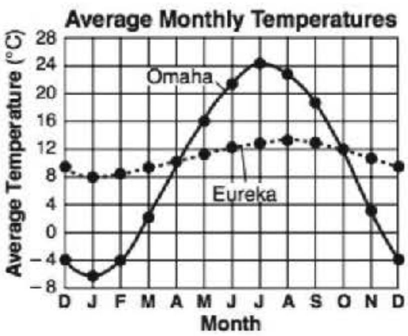
   - Since human bodies contain a large amount of water, the body temperature can be maintained at a more-or-less constant value of 37°C. Even when the surrounding temperature changes significantly, the change in temperature of human body is negligible.

3. ***Stabilizing environment temperature***

   - In coastal areas, land is surrounded by water. Since water has a smaller temperature change than that of the land when the same amount of heat is absorbed or released, as a result:

     ✓ Coastal area has cooler summer and warmer winter than the inland area of similar latitude and altitude.

     ✓ Coastal area has smaller temperature difference between daytime and nighttime.



Examples that you must fully understand

35. Which of the following is because of the high specific heat capacity of water?

(1) Congee is so hot even though it has been prepared for long time.

(2) Most of the power plants are built in coastal areas.

(3) In a beach, the temperature of sand is higher than that of sea water in nighttime.

(4) Water has a high boiling point.

36. A chinese style clay pot keeps food boiling for a short time even it has been removed from the fire. Why?

When the pot is [ ] from fire, its temperature is [ ] the boiling point of the food. [ ] from the pot to the food and keep it boiling.

As the pot has a [ ], it stores a lot of internal energy. Its temperature doesn't [ ] after losing heat to the food.

37. A swimming pool has a length of 50 m and a width of 25 m. The water depth is 2.4 m.

Given c of water = 4 200 J kg^{-1} ^{o}C^{-1}

(a) If the density of water 1 g cm^{-1}, what is the mass of water in the swimming pool?

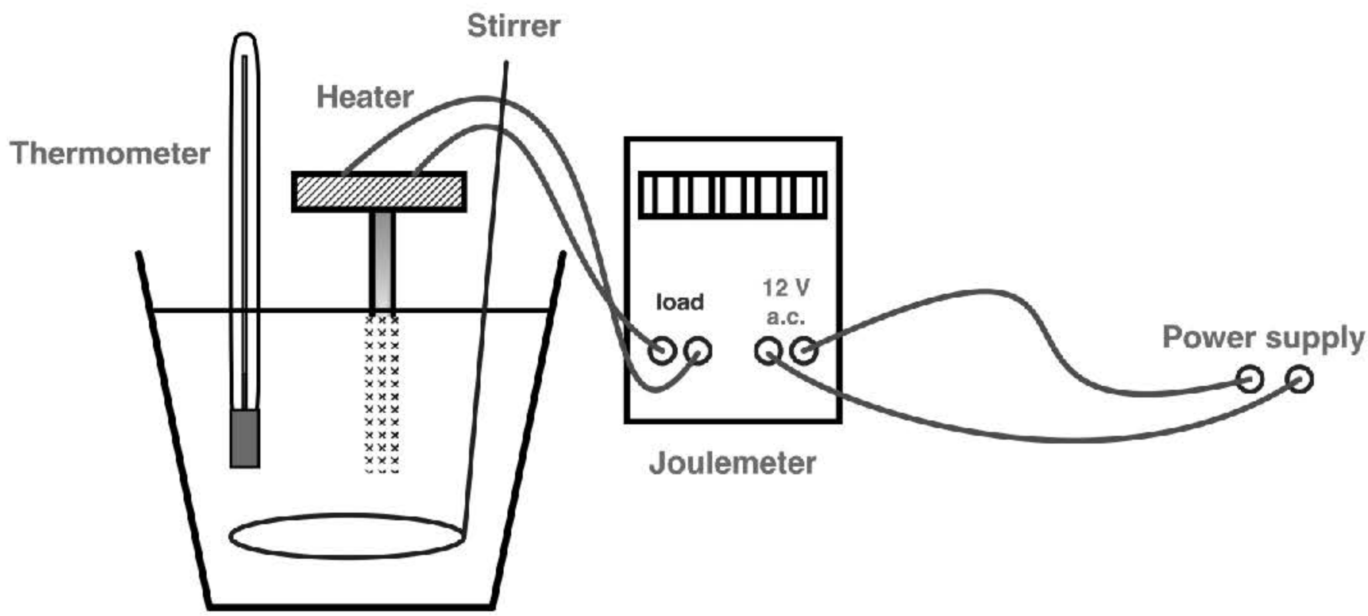
(b) In a shiny afternoon, water temperature can rise from 25^{o}C to 35^{o}C. Calculate the energy received by the pool water.

(c) Calculate the heat capacity of the pool water.

(d) Suppose there is a cooling system equipped in the pool to lower the temperature of pool water to 25^{o}C. Assume the cooling system can remove 4 J of heat in the expense of 1 J of electrical energy. If the cost of energy is $1.1 for one kW h, calculate the cost required for the cooling process.

6. Measurement of the Specific Heat Capacity of water

(1) Procedure of the experiment



1. *A certain amount of water with known mass, **m** is put into a polystyrene cup.*
2. *A heater is connected to a power supply through a joulemeter / kilo-watt hour meter is immersed into the water. The joulemeter or kilo-watt hour meter records the heat supplied, **Q**.*
3. *A thermometer is put inside the water to record the initial temperature, T_i and the final temperature T_f.*
4. *The specific heat capacity c can then be found by* $c = \dfrac{Q}{m \cdot (T_f - T_i)}$

(2) Sample calculation

Initial joulemeter reading = 24 300 J　　Final joulemeter reading = 38 700 J
Mass of the cup = 0.6 kg　　Mass of the cup with water = 0.85 kg
Initial temperature = 25 °C　　Final temperature = 38 °C

(3) Possible source of error

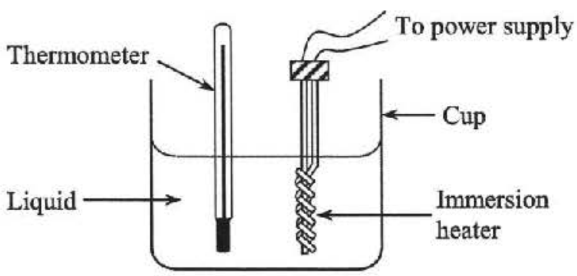
- The measured c is usually [ ] than the actual c recorded in a data book.
- This is because **some** [ ] **to the surrounding air and the apparatus**. Energy supplied by the heater is thus **greater** than the energy absorbed by the water.

(4) Precautions of the experiment

- A **stirred** should be used to well stir the water before taking the readings to **ensure that the water temperature is** [ ].
- **Polystyrene cup** should be used
  - **to reduce heat lost to the surrounding air as polystyrene is a good** [ ]**; and**
  - **to reduce the energy absorbed by the cup as the** [ ] **of a polystyrene cup is very small.**
- A **lid** should be used to cover the cup to **reduce heat lost** to the [ ].
- The **heater** should be **completely** [ ] **into the water** but should not touch the bottom of the cup.
- The **thermometer should not touch the** [ ].
- **Time should be allowed for water to reach the** [ ] **temperature** after the heater is [ ].

Examples that you must fully understand

38. A 100 W immersion heater is used to heat 0.5 kg of water, which is being stirred by a stirrer. After 3 minutes, the water temperature increases from 25 °C to 30 °C. What is the estimated energy loss in this period?
Given: specific heat capacity of water = 4200 J kg^{-1} °C^{-1}



Examples that you must fully understand

39. Billy is going to conduct an experiment to find the specific heat capacity of water with the following apparatus.

(1) beaker with 0.25 kg of water *(2) 50 W immersion heater*

(3) stopwatch *(4) thermometer*

(a) Describe how the experiment should be conducted. Specify all measurements that she has to take and write down the related equation.

Put the thermometer into the water to measure its ______, T_i.
Immerse the ______ into the water and switch on the power supply.
Record the ______, t by using a stopwatch.
Switch off the power supply and measure the ______, T_f.

The specific capacity can then be found by:

(b) Explain whether the following methods can improve the accuracy of the experiment or not.

(i) Replacing the beaker with a container with a smaller specific heat capacity.

The accuracy ______ since a container with smaller specific heat capacity doesn't mean it has a ______. As its ______ maybe larger than the original container, resulting in a ______ heat capacity, ______ ______ by the container leading to even larger value of measured specific heat capacity.

(ii) Decreasing the mass of water used in the experiment.

The ______ would become ______, thus accuracy ______.

(c) State and explain the effect on the measured value over the actual value in the following cases:

(i) The final temperature is recorded just after the heater is switched off.

The value of the specific heat capacity found would be ______ since ______ ______.

(ii) A metal cup is used instead of a polystyrene cup.

The value of the specific heat capacity found would be ______ since ______ ______.

(iii) The cup is not covered by a lid.

The value of the specific heat capacity found would be ☐ since ☐ ☐.

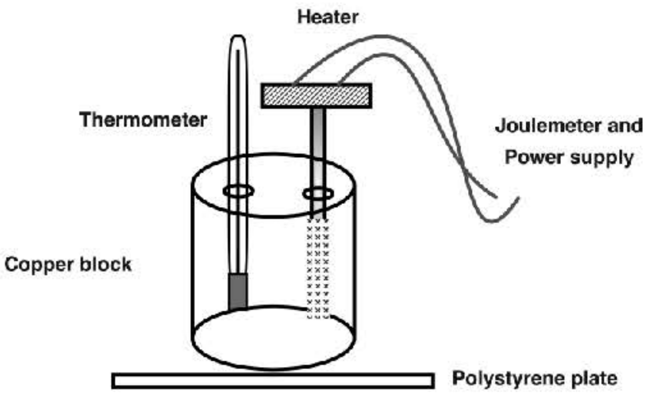
(iv) The thermometer is placed too close to the heater.

The value of the specific heat capacity found would be ☐ since ☐ ☐.

(v) No stirrer is used during the experiment.

The value of the specific heat capacity found would be ☐ since the rise in temperature recorded ☐ from the actual rise in the temperature of water due to ☐ temperature distribution.

40. The following apparatus is used to measure the specific heat capacity of a cylindrical copper block.



The result is shown below:

Initial joulemeter reading = 86 900 J

Final joulemeter reading = 95 500 J

Mass of the copper block = 0.75 kg

Initial temperature = 29°C

Final temperature = 54°C

(a) Calculate the specific heat capacity of copper and heat capacity of the copper block.

(b) Suggest two improvements to increase the accuracy of the result.

Add ☐ into the hole for placing the thermometer and the heater to ensure ☐ ☐.

☐ the copper block with ☐ such as ☐ to reduce heat loss to the surrounding air.

(c) Would you expect the value of the specific heat capacity found to be higher or lower than the normal value? Why?

The value of the specific heat capacity found would be ☐ than the actual value since there is ☐.

(d) Can this method be used for a piece of wood?

☐. Since a piece of wood is a ☐. The temperature distribution throughout it is non-uniform.

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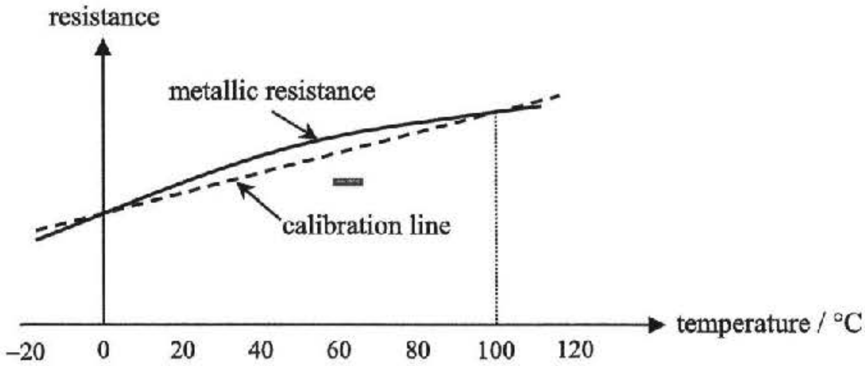
41. A metallic resistance thermometer is calibrated at standard atmospheric pressure for the melting point of ice and the steam point of boiling water. The dotted calibration line in the figure below represents how the resistance of the thermometer varies with temperature if a linear resistance-temperature relationship is assumed. The solid curve shows how the resistance of the thermometer actually varies with temperature. The deviation of the curve from linearity has been exaggerated in the figure.



(a) Using the resistances at the calibration points tabulated below, calculate the expected resistance at 60°C if the resistance varies linearly with temperature.

Temperature (°C)	Resistance / ohm
0	102.00
100	140.51

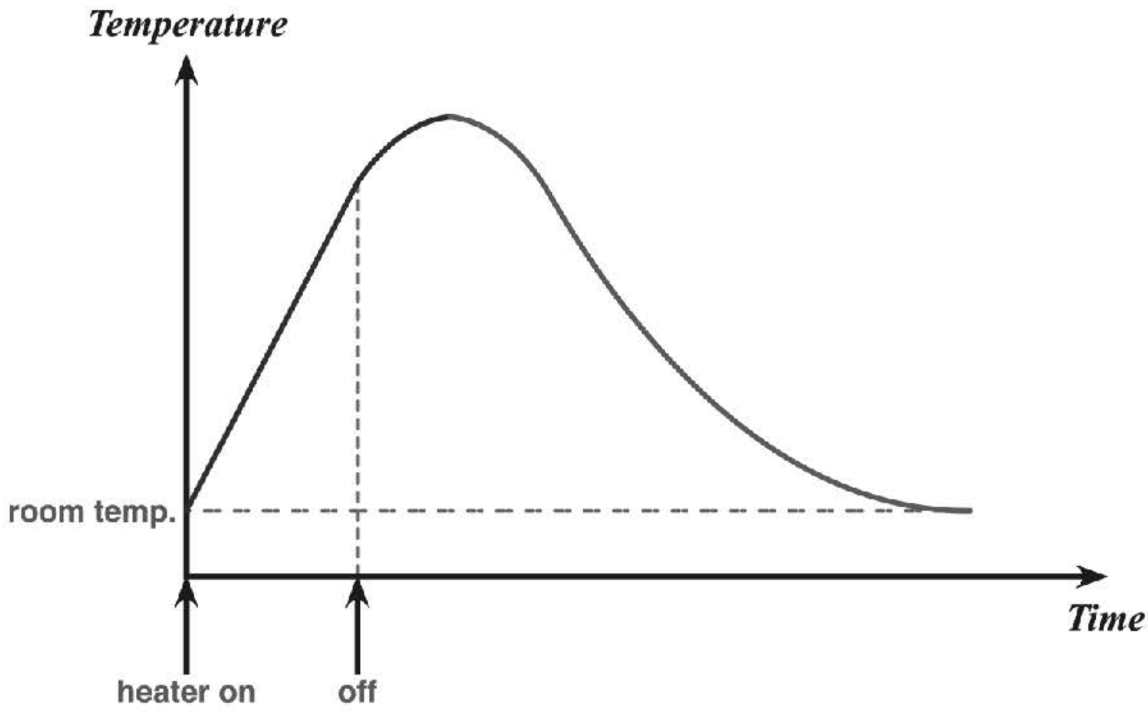
(b) Now if the resistance of the resistance thermometer is the value found in part (a), is the actual temperature higher than, lower than or equal to 60°C?

(c) In an experiment to determine the specific heat capacity of water c_w, Peter used this calibrated resistance thermometer to measure the temperature of water being heated from 0°C to 60°C. Heating was stopped when this thermometer's resistance reached the value found in (a). Assuming negligible heat exchange with the surroundings, no error in measuring the energy supplied and the mass of water, explain whether the experimental value of c_w found is higher than, lower than or the same as the actual value.

Since the measured temperature of 60°C is ______ than the actual temperature or the energy supplied is actually ______ than it should be,
the experimental value of c_w is ______ than the actual value.

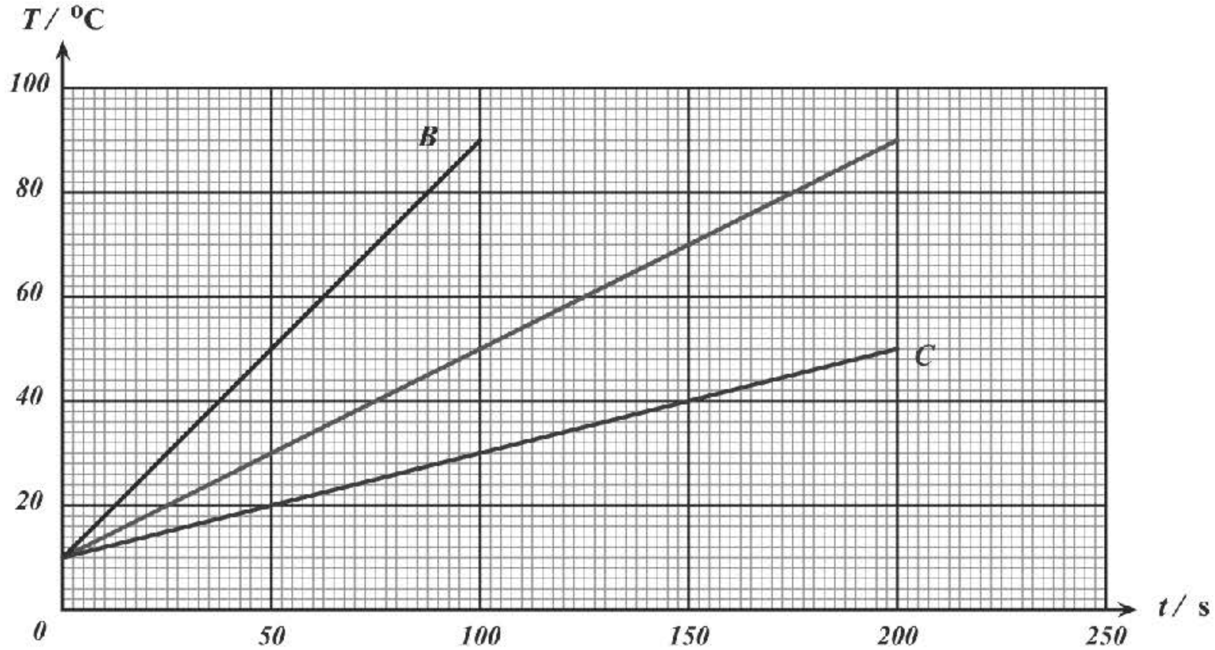
(5) Features of a temperature-time graph

- A temperature-time graph shows the variation of the temperature of a substance with time when the substance is heated by **a heater of constant power.**



Examples that you must fully understand

42. The figure shows the variation of temperature T with time t of a substance of mass m of 300 g being heated by a heater with a power P of 120 W. Assume no loss of energy to the surroundings.



(a) Find the specific heat capacity of the substance.

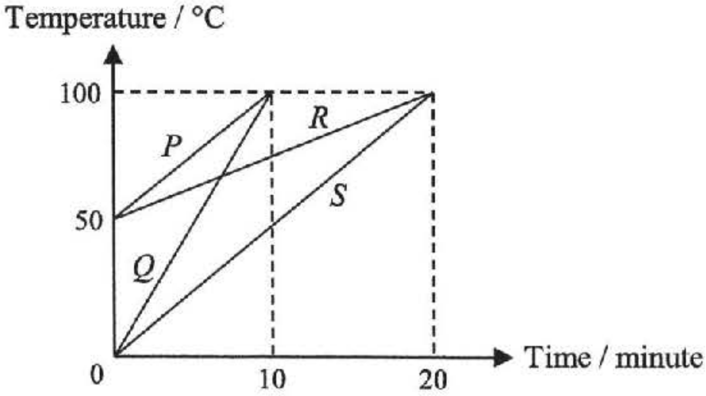
(b) Calculate the slope of the graph and find an expression of the slope.

(c) If the power of the heater is increased to 240 W, what would be the new slope of the graph? Sketch the curve on the diagram above, name as B.

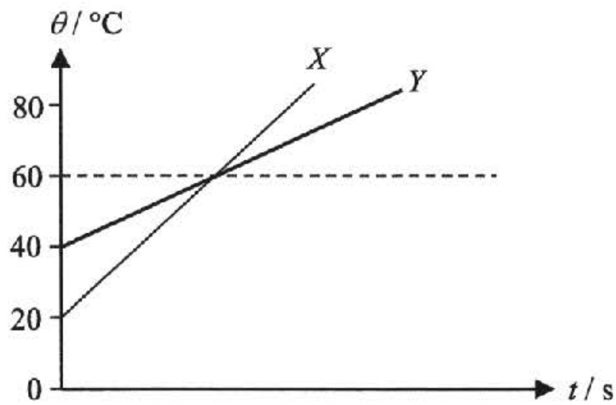
(d) If the mass of the substance is increased to 600 g while the power of the heater remains at 120 W, what would be the slope of the graph? Sketch the curve on the above diagram, name as C.

Examples that you must fully understand

43. Four liquids P, Q, R and S with the same mass are heated at the same rate. The graph below shows the variation of their temperatures with time. Which liquid has the highest specific heat capacity?



44. Two objects X and Y are heated separately by heaters of the same power. They are made of the same material. The graph shows the variation of temperature of X and Y with time t. What is the ratio of mass of X to that of Y?

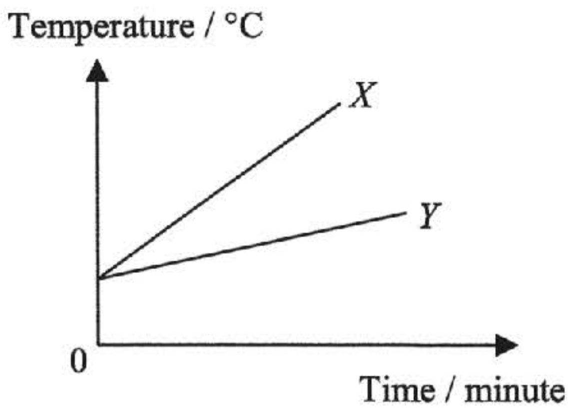


45. The figure shows the temperature-time graph of two objects X and Y when they are heated at the same power. Which of the following deductions are correct?

(1) The heat capacity of X is smaller.

(2) If X and Y are made of the same material, the mass of X is smaller.

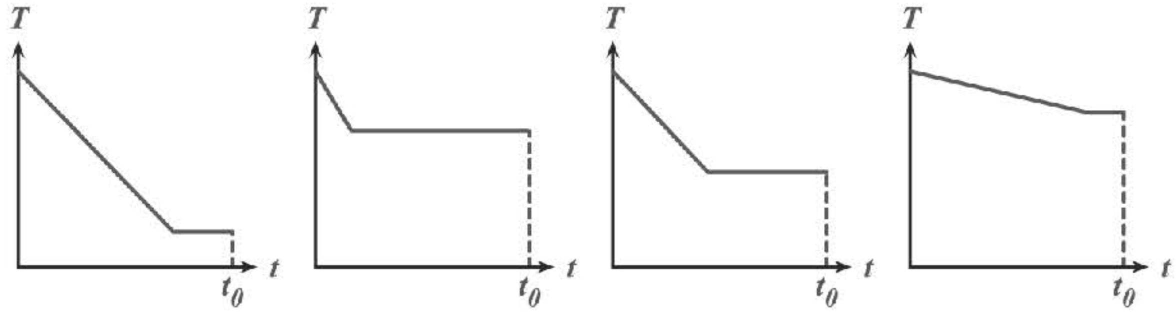
(3) The specific heat capacity of X is smaller.



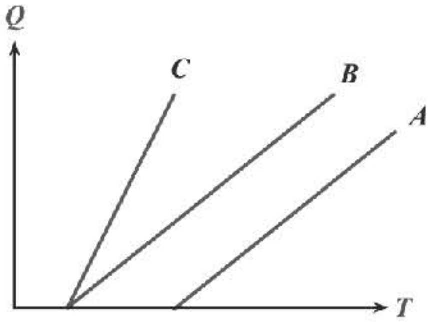
Examples that you must fully understand

46. Four different liquids of the same mass are cooled with the same cooling rate for a certain time. Their change in temperature is shown in the following cooling curve. Which liquid has the largest specific heat capacity?

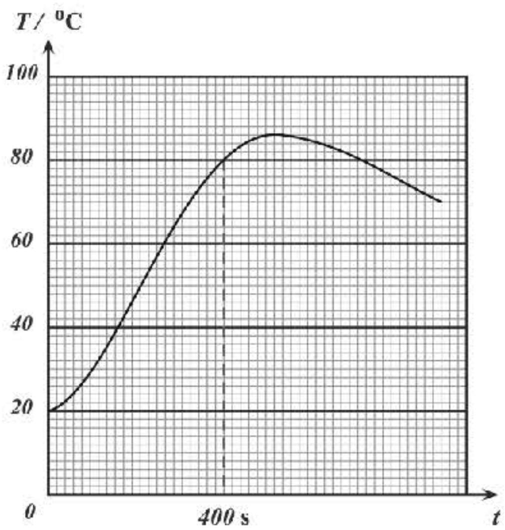
A. *B.* *C.* *D.*



47. Equal masses of liquids *A*, *B* and *C* are heated separately. The graph shows the variation of the heat *Q* absorbed by the liquids with their temperature *T*. Arrange the specific heat capacities of the three liquids in descending order.



48. Liquid *X*, contained in a plastic cup, is heated by an immersion heater. The heater is swithed on for 400 s. The variation of temperature of the liquid *X* with time is shown.



(a) After the heater is switched off, the temperature of the liquid contiues to cise for a while and then falls again. Explain why.

After the heater is ________, the heater is ____ ________.

Heat ________________ and therefore the liquid's temperature still ________.

After a while, there is ____________ ________, thus, teperature drops.

(b) What is the maximum increase in the tempertature of liquid X in the experioment? ________

(c) Suppose the lid covring the plastic cup is removed, what would be the effect on the maximum rise of temperature?

The maximum increase in temperature would be ______ since ________ ________________.

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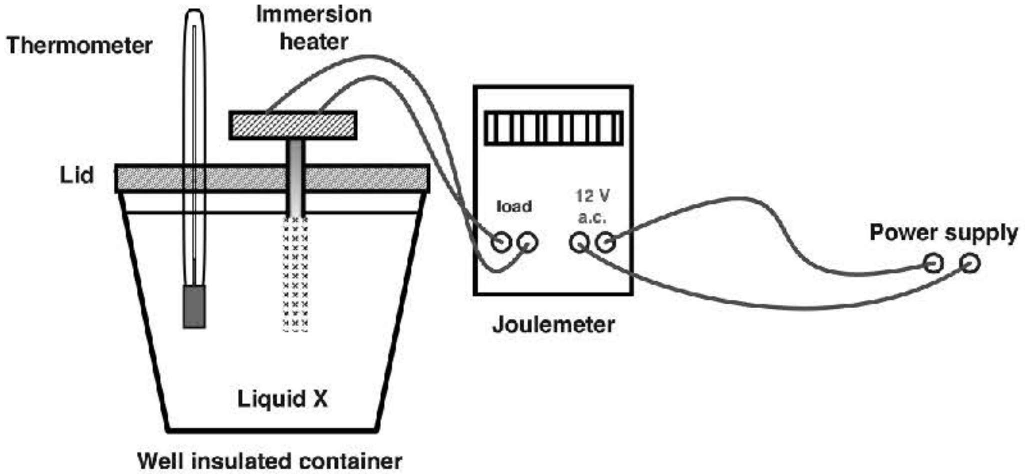
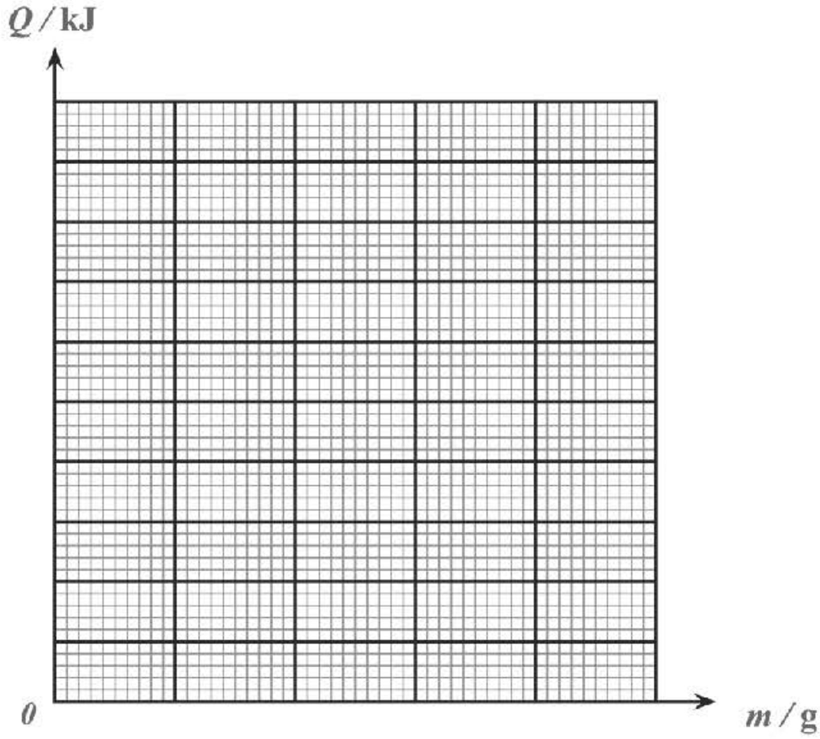
49. A student performs an experiment with the below set-up to measure the specific heat capacity of a liquid.



The increase in the reading of the joulemeter (Q) for an increase of temperature of 15°C (ΔT) for different mass (m) of liquid X is recorded in the table below.

Q/kJ	4.8	8.4	12.0	15.6	19.2
m/g	100	200	300	400	500

(a) Plot a graph of *Q* against *m* in the following figure.



(b) In this experiment, the heat lost to the surrounding air is assumed to be negligible. Please state the justification for this assumption.

Since the container is ________ and it is covered with a ____, the heat lost to the surrounding air can be neglected.

(c) Write down an equation relating *Q* and ΔT.

(d) What does the slope of the graph represent?

(e) Determine the specific heat capacity of the liquid *X* with the use of the graph.

(f) What is represented by the y-intercept of the graph?

It represents the ________________.

(g) Determine the heat capacity of the apparatus.

(h) Suggest an improvement to the above experiment.

Insert a ______ and ______ the liquid before taking each ______. It is to ensure that the temperature throughout the liquid is ______.

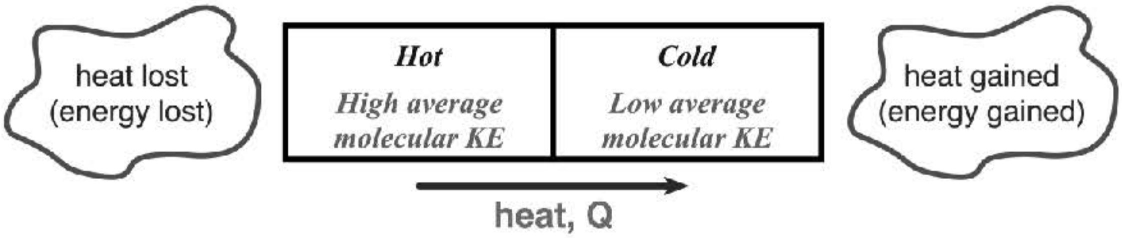
(i) Calculate the heat needed to increase the temperature of 1,200 g of liquid *X* in the container from 30°C to 75°C.

(j) If the experiment is repeated with liquid *Y* which has a greater specific heat capacity than that of the liquid *X*, sketch the graph to be obtained and label as *Y*.

7. Mixture of Hot and Cold Substances

(1) Principal of conservation of energy

- When two bodies of different temperature are put together, **heat flows from one with higher temperature to one with lower temperature until both reach the same temperature (thermal equilibrium).**



- With the assumption that no heat is lost to the surroundings:

Examples that you must fully understand

50. 30 g of milk at 10°C is added to 120 g of coffee at 80°C. Assuming there is no heat loss to the surroundings, what is the final temperature of the mixture?
(Given: Specific heat capacity of milk = 3800 J kg^{-1} °C^{-1}; heat capacity of coffee = 504 J kg^{-1} °C^{-1})

51. 0.8 kg of green tea at 90°C is mixed with 0.6 kg of green tea at 20°C. Assuming that no heat is lost to the surroundings, find the final green tea temperature.

A. 55°C

B. 60°C

C. 65°C

D. *Cannot be determined as the specific heat capacity of green tea is not given*

Examples that you must fully understand

52. A copper block at 80°C is put into 1.6 kg water at 20°C. Assume that no heat is lost to the surroundings. If the final temperature of the mixture is 35°C, find the mass of the copper block.
(Given: Specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ °C}^{-1}$; specific heat capacity of copper = $380 \text{ J kg}^{-1} \text{ °C}^{-1}$)

53. Two metal blocks X and Y of the same mass and of initial temperatures 40°C and 30°C respectively are in good thermal contact. The specific heat capacity of X is greater than that of Y. Which statement(s) is / are correct when a steady state is reached? Assume no heat loss to the surroundings.

(1) The temperature of block X is higher than that of block Y.

(2) Their temperature becomes the same and is lower than 35°C.

(3) Their temperature becomes the same and is higher than 35°C.

(4) Their temperature becomes the same is equal to 35°C.

54. When hot water (at T_H) is mixed with cold water (at T_C), which of the following must be true? You can assume no heat is lost to the surroundings.

(1) The temperature of the final mixture is the average of both temperatures (i.e. = $(T_H + T_C)/2$).

(2) The average molecular KE of the final mixture is the average of the average molecular KE of the hot water and that of cold water.

(3) The specific heat capacity of the final mixture is the average of the specific heat capacity of the hot water and the specific heat capacity of the cold water.

55. A bath is filled up by a hot water tap and a cold water tap. Hot water at 70°C is poured at a rate of 0.1 kg per second while cold water at 20°C fills the bath at a rate of 0.14 kg per second. The two taps are turned on at the same time. The hot water tap is turned off after 2 minutes, and 1 minute later the cold water tap is also stopped. Assume 10% of heat released by the hot water is lost to the surroundings. Find the final water temperature of the bath. (Given: Specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ °C}^{-1}$)

Examples that you must fully understand

56. A metal ball of mass 0.4 kg is heated by a Bunsen flame. The temperature of the ball is later found to increase to a maximum steady value.

(a) Explain why the temperature of the metal increases.

Since the temperature of the metal ball is ______ than that of the Bunsen flame, ______ ______, increasing its temperature.

(b) How do you compare the steady temperature of the metal ball and the temperature of the Bunsen flame?

The maximum temperature of the metal ball ______ the temperature of the flame since ______ ______

(c) Explain why the temperature of the ball stays at a steady value and does not increase further.

(d) The ball is then put into 1.2 kg of water at 20°C and the final temperature of the mixture becomes 50°C. Find the temperature of the metal ball just before it was put into the water.

c of water = 4200 J kg^{-1} °C^{-1}, heat capacity of the metal ball = 160 J °C^{-1}

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57. 1 kg of water is mixed with 4 kg of alcohol. (c of water = 4 200 J kg^{-1} °C^{-1}, c of alcohol = 2 100 J kg^{-1} °C^{-1})

(a) Find the total energy needed to raise the temperature of the mixture by 10°C.

(b) Find the heat capacity of the mixture.

(c) Find the specific heat capacity of the mixture.

58. The following example is about 雲南過橋米線. When customers order this food, the following items are served:

A bowl of hot soup with a layer of oil on the surface

A dish of thin slices of raw meat

A bowl of pre-cooked noodles

The correct steps of preparing the food are to put the meat into the soup first, and then add the noodles after a while.

(a) State two advantages of placing a layer of oil over the surface of the hot soup.

The layer of oil can [ ] from the soup to the surrounding air. The layer of oil can [ ] of the soup.

(b) What is the advantage of cutting the meat into thin slices?

It can increase the [ ] between the soup and the meat so that heat can be transferred to the meat [ ].

As the mass of each thin slice is small, the [ ] of each thin slice is also small. The meat [ ].

(c) In a standard size of 雲南過橋米線, the food is served with the following data:

Mass of the soup = 1.2 kg
Mass of each slices of meat = 0.02 kg
Number of slices = 12
Initial temperature of the soup = 97 °C
Initial temperature of the meat = 27 °C
Specific heat capacity of the soup = 4 200 J kg^{-1} $°C^{-1}$
Specific heat capacity of the meat = 3 500 J kg^{-1} $°C^{-1}$

(i) What is the final temperature of the soup after all the slices of meat have been added into the soup?

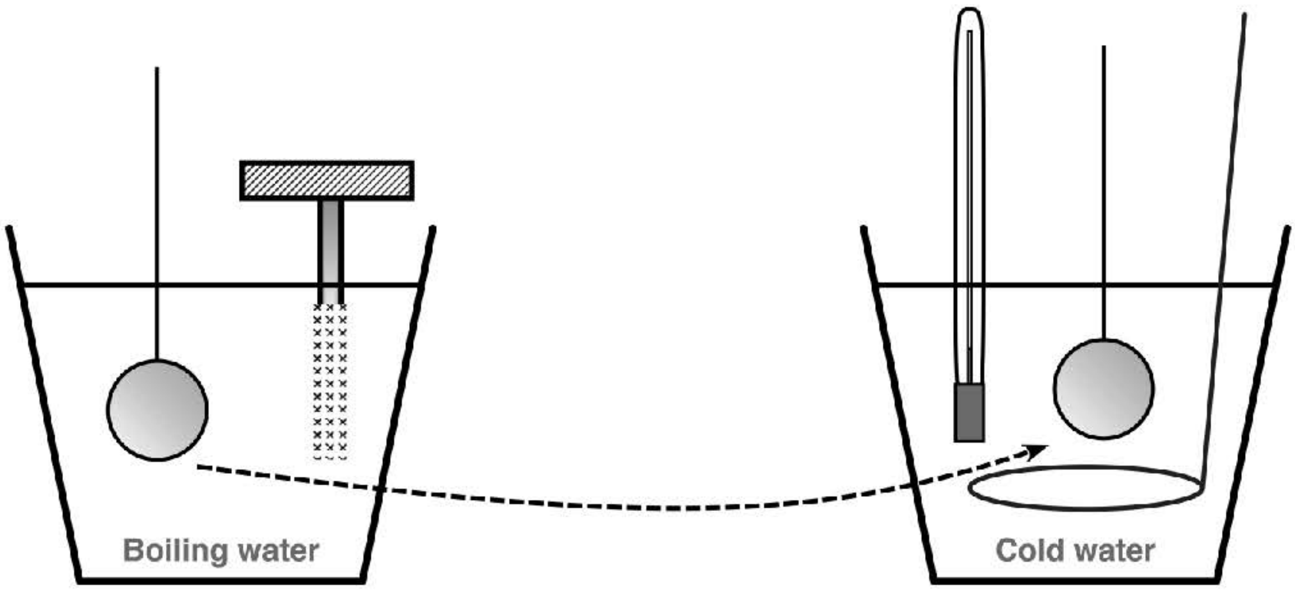
(ii) What is the basic assumption in the calculation in part (c)(i)?

Assume there is [ ].

(iii) A customer first places the noodles into the soup before adding the meat. Explain why this is undesirable.

If the noodles are placed into the soup first, the [ ] [ ], thus the soup will not be [ ] to a safe temperature.

(2) Finding the specific heat capacity by the method of mixture



- The specific heat capacity of a metal ball is found by the following procedures:
  - *The metal block is immersed in boiling water for some time until it reaches the temperature of the water.*
  - *It is then transferred to a cup of cold water.*
  - *After well stirred the final temperature of the mixture is measured by a thermometer.*

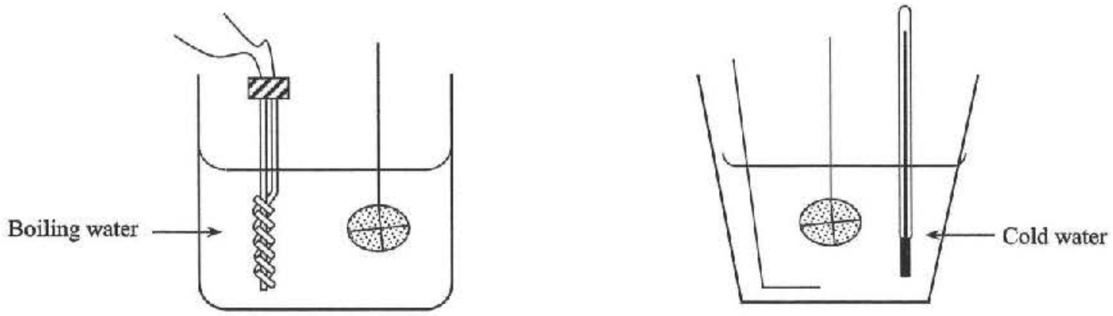
- The following data is recorded:

Initial temperature of the cold water = 29 °C	Mass of the metal block = 0.5 kg
Final temperature of the water = 35 °C	Mass of boiling water = 1.25 kg
Specific heat capacity of water = 4 200 J kg^{-1} °C^{-1}	Mass of cold water = 0.75 kg

- However, the value calculated in can deviate from the value in the data book, because:
  - ***Since some hot water is still ______ to the metal block when it is transferred to the cold water, the result obtained would be ______ than the actual value.***
  - ***Since some energy from the metal block is ______ to the surrounding air and the cup, the result obtained would be ______ than the actual value.***

Examples that you must fully understand

59. The specific heat capacity of a metal can be measured using the following method:



A metal block is first immersed in boiling water for some time. The block is then transferred to a cup of cold water. After a while, the temperature of the water is measured. The result of the experiment is as follows:

Mass of metal block = 0.8 kg

Mass of water in the cup = 0.3 kg

Initial temperature of water in the cup = 23°C

Final temperature of water in the cup = 38°C

Given the specific heat capacity of water = 4200 J kg^{-1} $°C^{-1}$

(a) Find the specific heat capacity of the metal.

(b) In each of the following cases, state whether the measured value would be higher than or lower than the actual value of the specific heat capacity of the metal.

(i) Some hot water is still adhered to the metal block when the block is transferred to the cold water.

The measured value will be ______ than the actual value since ______ is carried by the hot water on the metal block.

(ii) Some energy is lost to the surroundings when the metal block is transferred to the cold water. Or Some energy is absorbed by the cup.

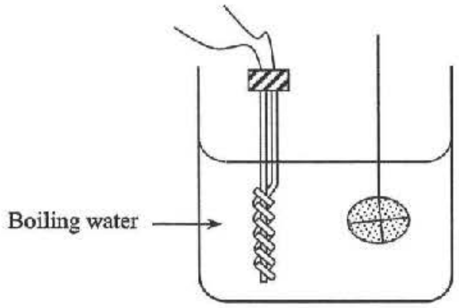
The measured value will be ______ than the actual value since ______ is transferred to the cold water.

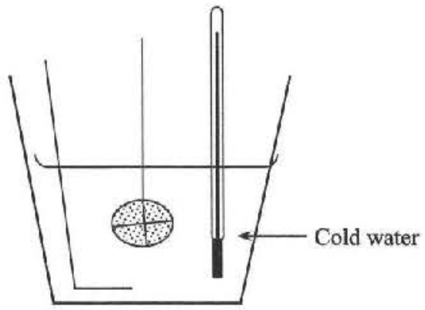
(iii) The temperature of the metal block is still higher than 38°C when the final temperature of the water in the cup is measured.

The measured value will be ______ than the actual value since ______ is transferred to the cold water.

Examples that you must fully understand

60. The specific heat capacity of water can be measured using the following method:





A metal block is first immersed in boiling water for some time. The block is then transferred to a cup of cold water. After a while, the temperature of the water is measured. The result of the experiment is as follows:

Mass of metal block = 0.8 kg

Mass of water in the cup = 0.3 kg

Initial temperature of water in the cup = 23°C

Final temperature of water in the cup = 38°C

Given the heat capacity of the metal block = 304.84 J °C^{-1}

(a) Find the specific heat capacity of water.

(b) In each of the following cases, state whether the measured value would be higher than or lower than the actual value of the specific heat capacity of water.

(i) Some hot water is still adhered to the metal block when the block is transferred to the cold water.

The measured value will be ______ than the actual value since ____________ is carried by the hot water on the metal block.

(ii) Some energy is lost to the surroundings when the metal block is transferred to the cold water. Or Some energy is absorbed by the cup.

The measured value will be ______ than the actual value since ____________ is transferred to the cold water.

(iii) The temperature of the metal block is still higher than 38°C when the final temperature of the water in the cup is measured.

The measured value will be ______ than the actual value since ____________ is transferred to the cold water.