CHAPTER ELEVEN

SPECIFIC HEAT CAPACITY AND HEAT CAPACITY

The specific heat capacity:

- The specific heat capacity of a substance is defined as the heat required to raise a unit mass of it through 1^{0c}.
- Its S.I unit is J/Kg^0C, and the symbol used to represent it is C.
- This mass refers to a mass of 1kg.

The heat capacity:

- This is also known as the thermal capacity.
- The heat capacity of a substance or a body is defined as the heat required to raise it temperature by 1^0c.
- The S.I unit for the heat capacity is joule per degree Celsius i.e. $J/^0C$ or $J/^0k$.
- The heat capacity = mass × specific heat capacity.

(Q1) The specific heat capacity of copper is $400J/kg^0C$. Find the heat capacity of 5kg of copper.

Soln:

Since heat capacity = mass × specific heat capacity,

=> heat capacity = $5 \times 400 = 2000Jk^{-1} = 2000J/k = 2kJ/k$

N/B: 2kJ/ k is the same as $2kJk^{-1}$.

Also 40J/k can also be written as $40Jk^{-1}$.

(Q2) Calculate the heat capacity of a substance whose specific heat capacity is $25Jk^{-1}\,^0C^{-1}$, if it has a mass of 10kg.

Soln:

Mass = M = 10kg.

Specific heat capacity = C = 25J/kg^{0}C.

Heat capacity = MC = 10×25

= 250J/^{0}C.

(Q3) The mass of a substance is 4000g. If its specific heat capacity is 50J/kg^{0}C, determine its heat capacity.

Soln:

M = 4000g = 4kg.

C = 50J/kg^{0}C.

Heat capacity = MC

= 4×50 = 200J/^{0}C = 0.2Kj/^{0}c.

N/B: (1) 1kJ = 1000J and 1kg = 1000g.

(1) The heat gained by a substance = M $\times$ C $\times \triangle\theta$, where M = the mass of the substance in kg.

C = its specific heat capacity.

$\triangle\theta$ = the change in temperature.

(2) The heat lost by a substance or a body is also = M $\times$ C $\times \triangle\,\theta$.
$where \triangle\theta$ = the increase (rise) or decrease (fall) in temperature.

(Q1) The specific heat capacity of a substance is 20J/kg^{0}C. If the substance has a mass of 15kg and it temperature rises by 10^{0}C, calculate the heat gained by the substance.

Soln:

C = 20J/kg^{0}C.

$M = 15kg$.

$\triangle\theta = 10^{0C}$.

Heat gained = $M \times C \times \triangle\theta$

$= 15 \times 20 \times 10 = 3000J = 3kJ$.

(Q2) The mass of a metal is 7000g and its specific heat capacity is $30Jkg^{-1}c^{-1}$. If its temperature is raised from 4^{0c} to 6^{0C}, determine the amount of heat energy that it will gain.

Soln:

$M = 7000g = 7kg$.

$C = 30Jkg^{-1} = 30J/kg$.

$\triangle\theta = 6 - 4 = 2^{0C.}$

Amount of heat gained = $M \times C \times \triangle\theta = 7 \times 30 \times 2 = 420J$.

N/B:

Heat gained or lost by a body = $M \times C \times \triangle\theta$.

But since $m \times c$ = the heat capacity,

then heat lost or gained by a body = $m \times c \times \triangle\theta$ = Heat capacity $\times \triangle\theta$.

(Q3) The heat capacity of a substance is $320J/^{0}C$. If its temperature is increased by 4^{0c}, determine the amount of heat gained.

Soln:

Heat gained = heat capacity $\times$ rise in temperature.

Therefore heat gained = $320 \times 4 = 1280J = 1.28kJ$.

(Q4) The temperature of a substance was decreased by 8^0C. If it has a mass of 50kg, and a specific heat capacity of 10J/kg^{0}C, determine the amount of heat lost by the substance.

Soln:

$\triangle\theta$ = 8^0c

c = 10J/ kg^{0}C.

m = 50kg.

Heat lost = m $\times$ c $\times$ $\triangle\theta$

= 50 $\times$ 10 $\times$ 8 = 4000J = 4kJ.

(Q5) The heat capacity of a body is 200J/ kg ^{0}C. If its temperature falls from 22^{0}C to 20^{0}C, calculate the amount of heat lost.

Soln:

Heat capacity = m $\times$ c = 200J/ ^{0}C.

$\triangle\theta$ = 22 – 20 = 2^{0}C.

Heat lost = Heat capacity x change in temperature = 200 $\times$ 2 = 400J

Soln:

Fall in temperature = $\triangle\theta$ = ?

M = 200g = 0.2kg.

C = 10Jkg^{-10}c^{-1}

Heat lost = 12J.

But since heat lost = M $\times$ C $\times$ $\triangle\theta$

N/B:

(I) 10J.kg^{-10}C^{-1} is the same as or equivalent to 10Jkg^{-10}k^{-1}.

(II) Also $10Jkg^{-10}k^{-1}$ can also be written as $10J/kg^{0}k$.
(III)In short, degrees kelvin and degrees celcius are interchangeable.

(Q6) Given that the heat capacity of a metal is $80J/kg\ ^{0}k$, find its specific heat capacity, if it has a mass of 5kg.

Soln:

Heat capacity = $80J/^{0}k$.

M = 5kg, C = ?

Since heat capacity = $m\times c$,

=> heat capacity = $5 \times c$, => 80 = 5c,

=> c = $\frac{80}{5} = 16.$

The specific heat capacity = $1\ 6J/kg^{0}k$.

N/B:

- The change in temperature (i.e. the increase or decrease in temperature) $\triangle\theta$ is also = $\theta_2 - \theta_1$, where θ_2 = the higher temperature and θ_1 = the lower temperature

Therefore heat lost or heat gained = $m \times c \times \triangle\theta$ = $m \times c \times (\theta_2 - \theta_1)$.

(Q1) How many jouls of heat is given out, when a piece of iron of mass 2kg and specific heat capacity $460J/kg^{0}C$, cools from $30^{0}C$ to $20^{0}c$.

Soln:

M = 2kg, C = $460J/kg^{0}C$, $\theta_2 = 30^{0}C$ and $\theta_1 = 20^{0c}$.

Heat given out = $m \times c \times (\theta_2 - \theta_1)$

= $2 \times 460 \times (30 - 20)$

= $2 \times 460 \times 10$ = 9200J = 9.2kJ.

(Q2) Determine the amount of heat given out, when 50g of iron cools from 45^0C to 15^0C, if its specific heat capacity is 460J/kg^{0}C.

Soln:

$\theta_2 = 45^0C$, $\theta_1 = 15^0C$,

m = 50g = 0.05kg, c = 460J/ kg^{0}C.

Heat given out = $m \times c \times (\theta_2 - \theta_1)$

$= 0.05 \times 460 \times (45 - 15)$

$= 0.05 \times 460 \times 30 = 690J$

N/B:

- θ_2 may also be referred to as the final temperature.
- θ_1 may also be referred to as the initial temperature.
- $(\theta_2 - \theta_1)$ = the change in temperature.

(Q3) (a) Explain what is meant by the statement, the specific heat capacity of iron is 460J/kg^{0}C.

Soln:

This means that when the temperature of 1kg of iron changes by 1^{0c}, the heat given out or taken in is 460J.

(Q4) What will be the final temperature of the mixture, if 100g of water at a temperature 70^0C is added to 200g of cold water whose temperature is 10^{0c} and well stirred. Neglect the heat absorbed by the container. [Specific heat capacity of water = 4200J/kg^{0}C].

Soln:

Heat given out by hot water = Heat gained by cold water.

Let θ = the final temperature of the mixture.

With reference to the hot water, θ, the final temperature of the mixture will be lower than the temperature of the hot water (i.e. 70^0C).

=> For the hot water, the change in temperature = $(70^0 - \theta)$.

Heat lost by hot water when it cools from 70^0C to θ^0C = m $\times$ c $\times$ (70 - θ)

= 100g $\times$ 4200 $\times$ (70 - θ)

= 0.1kg $\times$ 4200 $\times$ (70 - θ).

With reference to the cold water, the final temperature of the mixture which is θ, will be higher that the temperature of the cold water, (10^0C).

=> The change in temperature of the cold water = (θ - 10).

The heat gained by the cold water in warming from 10^0C to θ^0C = m $\times$ c $\times$ (θ - 10)

= 200g $\times$ 4200 $\times$ (θ - 10)

= 0.2kg $\times$ 4200(θ - 10).

Since heat lost by hot water = heat gained by cold water,

=> $0.1 \times 4200 \times (70 - \theta) = 0.2 \times 4200 \times (\theta - 10)$,

=> $420(70 - \theta) = 840 (\theta - 10)$, => $29400 - 420 \theta = 840 \theta - 8400$,

=> $29400 + 8400 = 840 \theta + 420 \theta$,

=> $37800 = 1260 \theta$

=> $\theta = \frac{37800}{1260} = 30^0$C.

The final temperature of the mixture = 30^0C.

(Q5) A piece of copper of mass 250g was heated to 100^0C, and then transferred into a well lagged aluminum can of mass 10.0g, which contained 120g of methylated spirit whose temperature was 10^0C. Determine the final steady temperature of the mixture, after the spirit had been well stirred. [The specific heat capacity of copper = 400J/kg^{0}C, of aluminum = 900J/kg^{0}C, of methylated spirit = 2400J/kg^{0}C].

N/B:

- Since the methylated spirit was contained within the aluminum can, => heat gained by the aluminum can + the heat gained by the methylated spirit = heat lost by the piece of copper.
- Secondly, since the methtylated spirit is within the aluminium can(i.e. in contact with each other), then they will also have the same temperature.
- Therefore if the temperature of the methylated spirit is 10^0C, then that of the aluminium can will also be 10^0C.

Soln:

Let θ = the final temperature of the mixture.

Sine the initial temperature of the copper (i.e. 100^0C) will be higher than this θ,

=> change in temperature = $(100 - \theta)$.

Heat lost by the copper in cooling from 100^0C to $\theta = m \times c \times (100 - \theta)$

$= 250g \times 400 \times (100 - \theta) = 0.25kg \times 400 \times (100 - \theta) = 100(100 - \theta) = 10,000 - 100\theta$.

Since the hot piece of copper was dropped into the aluminum can which contained the methylated spirit whose temperature was 10^0C, then the final temperature θ will be higher than this 10^0C, which is the initial temperature of both the aluminum can and the methylated spirit.=> For both the aluminium can and the methylated spirit, the change in temperature = $(\theta - 10^0C)$.Heat gained by the aluminum can = $m \times c \times (\theta - 10^0C)$

$= 10g \times 900 (\theta - 10)$

$= 0.01kg \times 900 \times (\theta - 10)$

$= 9(\theta - 10) = 9\theta - 90$.

Lastly, heat gained by the methylated spirit = $m \times c \times (\theta - 10)$

$= 120g \times 2400 \times (\theta - 10)$

$= 0.12kg \times 2400 \times (\theta - 10)$

$= 288(\theta - 10) = 288\,\theta - 2880.$

Since the heat lost by the copper = the heat gained by the aluminum can + the heat gained by the methylated spirit, then $10000 - 100\theta = 9\theta - 90 + 288\,\theta - 2880$,

$=> 10{,}000 + 90 + 2880 = 9\theta + 288\theta + 100\theta$,

$=> 12970 = 397\theta$

$=> \theta = \frac{12970}{397} = 33$

=> The final temperature = 33^0C.

(Q6) 500g of a certain metal was heated to 100^0C, and then placed in a 200g of water whose temperature was 15^0C. If the final temperature of the mixture rose to 20^0C, calculate the specific heat capacity of the metal.

N/B: The final temperature will be the same for both the metal and the water.

[Specific heat capacity of water = 4200J/kg^{0}C].

Soln:

<u>For the metal:</u>

Let C = the specific heat capacity.

Mass = 500g = 0.5kg.

Initial temperature = 100^0C.

Final temperature = 20^0C.

Change in temperature = $\Delta\theta$

$= 100 - 20 = 80^0$C.

Heat lost by the metal = $m \times c \times \Delta\theta = 0.5 \times c \times 80 = 40c$J

.

For the water:

Mass = 200g = 0.2kg.

Specific heat capacity = 4200J/kg^{0}C.

Initial temperature = 15^{0c}

Final temperature = 20^{0c}

Change in temperature = θ

= 20 – 15 = 5^{0c}

Heat gained by water = m $\times$ c $\times \Delta\theta$ = 0.2$\times$4200 $\times$ 5 = 4200J.

But since heat lost by metal = heat gained by water => 40C = 4200, => C = $\frac{4200}{40}$

=> C = 105J/kg^{0}C.

(Q7) A brass cylinder of mass 100g was heated to 100^{0}C, and then transferred into a thin aluminium can of negligible heat capacity, containing 150g of paraffin whose temperature was 11^{0}C. If the final steady temperature after stirring was 20^{0}C, calculate the specific heat capacity of the paraffin. [The specific heat capacity of brass = 0.38J/kg^{0}C].

N/B: - Since the aluminum can has negligible heat capacity, then we do not consider it during calculation.

- Therefore in this particular case, the heat lost by the brass = the heat gained by the paraffin only.

Soln:

For the brass:

Mass = 100g = 0.1kg.

Initial temperature = 100^{0}C.

Final temperature = 20^0.

$\triangle\theta$ = 100 – 20 = 80^0c.

c = 0.38J/kg^{0}C.

Heat lost by the brass in cooling from 100^0C to 20^0C = m $\times$ c $\times\triangle\theta$ = 0.1 $\times$ 0.38 $\times$ 80 = 3.04J.

For the paraffin:

Mass = 150g = 0.15kg.

Specific heat capacity = C.

Initial temperature = 11^0C.

Final temperature = 20^0C.

$\triangle\theta$ = 20 – 11 = 9^0C.

Heat gained by the paraffin = m $\times$ c $\times\triangle\theta$ = 0.15 $\times$ c $\times$ 9

= 1.35C.

But heat lost by brass = heat gained by the paraffin.

=> 3.04 = 1.35c

=> c = $\frac{3.04}{1.35} = 2.3$

Since c = specific heat capacity of paraffin => the specific heat capacity of paraffin = 2.3J/kg^{0}C.

N/B: The thermal capacity or the heat capacity of the paraffin = mass $\times$ specific heat capacity = 0.15 $\times$2.3 = 0.345J/^{0}c.

(Q8) A metal of mass 2kg and of heat capacity 32J/^{0}c and whose temperature was 30^0c, was dropped into a liquid of mass 4kg, and whose specific heat capacity was 40J/kg^{0}c. If the temperature of the liquid was 10^0C, calculate the final temperature of the mixture.

N/B: - In this case, the specific heat capacity of the metal is not given but rather its heat capacity.

Soln:

Mass of metal = 2kg.

Heat capacity of the metal = $32J/^0C$.

Specific heat capacity = ?

Since heat capacity = m $\times$ c,

=> 32 = m $\times$ c => 32 = 2 $\times$ c,

=> 2c = 32 => c = $\frac{32}{2} = 16.$

=> The specific heat capacity of the metal = $16J/kg^0c$.

Initial temperature of the metal = 30^0c.

Let θ = the final temperature of the mixture.

Since the initial temperature of the metal will be higher than the final temperature of the mixture, then the change in temperature of the metal = $\triangle\theta$ = $(30 - \theta)$.

Heat lost by the metal = m $\times$ c $\times$ $(30 - \theta)$ = 2 $\times$ 16 $\times$ $(30 - \theta)$.

Mass of the liquid = 4kg.

Specific heat capacity of the liquid = $40J/kg^0C$.

Initial temperature of the liquid = 10^0C.

Since the hot metal was dropped into this liquid, then θ, the final temperature of the mixture will be higher than the 10^0c.

=> change in temperature of the liquid = θ - 10^0.

Heat gained by the liquid = m $\times$ c $\times$ $(\theta - 10)$ = 4 $\times$ $40(\theta - 10)$.

But heat lost by the metal = heat gained by the liquid.

=> 2 $\times$ 16 $\times$ $(30 - \theta)$ = 4 $\times$ $40(\theta - 10)$,

=> $32(30 - \theta) = 160(\theta - 10)$,

=> $960 - 32\theta = 160\theta - 1600$,

=> $960 + 1600 = 160\theta + 32\theta$,

=> $2560 = 192\theta$,

=> $\theta = \frac{2560}{192}$

= 13.3.The final temperature of the mixture = 13.3^0C.

(Q9) A piece of copper of mass 40g and at a temperature of 200^0c, is to be placed into a copper calorimeter of mass 60g, containeing 50g of water whose temperature is 10^0c. Ignoring heat losses, determine the final steady temperature after stirring. [Specific heat capacity of copper = 0.4J/g^{0}c, and that of water is 4.2J/g^{0}c].

N/B: Since the masses are in grams and the specific heat capacities are given in joule/ grams, there is no need to convert the masses in grams into kg.

Soln:

Let θ = the final steady temperature of the mixture.

<u>For the piece of copper:</u>

Mass = 40g.

C = 0.4J/g^{0}c.

Initial temperature = 200^0c.

Change in temperature = $200 - \theta$.

Heat lost by the piece of copper = $40 \times 0.4 \times (200 - \theta)$

<u>For copper calorimeter:</u>

Mass = 60g.

C = 0.4J/g^{0}c.

Initial temperature = 10^0c.

Change in temperature = (θ - 10).

Heat gained = 60 × 0.4 × (θ - 10)

<u>For the water:</u>

Mass = 50g

C = 4.2J/g^0c.

Change in temperature = (θ - 10).

Heat gained by water = 50 × 4.2 × (θ - 10).

But since at equilibrium, heat lost by the piece of copper = heat gained by the colorimeter + heat gained by the water.

=> $40 \times 0.4(200 – \theta) = 60 \times 0.4(\theta - 10) + 50 \times 4.2(\theta - 10)$.

=> $16(200 – \theta) = 24(\theta - 10) + 210(\theta - 10)$,

=> $3200 - 16\theta = 24\theta - 240 + 210\,\theta - 2100$,

=> $5540 = 234\theta$, => $\theta = \frac{5540}{234} = 24^0$c.

The final steady temperature after stirring = 24^0c.

(Q10) 200g of a liquid at a temperature of 21^0c was heated to 51^0c, by a current of 5A at 6v for 5 minutes. Neglecting the heat losses, calculate the specific heat capacity of the liquid in J/kg^0c.

N/B: - The mass is given in grams and the specific heat capacity is to be calaculated in J/kg^0c.

- The mass must therefore be converted into kg.
  Soln:
  Mass of liquid = 200g = 0.2kg and specific heat capacity of liquid = c = ?
  Change in temperature of the liqud = $\triangle\theta = 51 – 21 = 30^0$c.

Heat gained by the liquid = m $\times$ c $\times \triangle\theta$ = 0.2 $\times$ c $\times$ 30 = 6c.
Current = I = 5A.
Potential difference = V = 6V.
Time = 5 minutes = 5 $\times$ 60 = 300 seconds.
Electrical energy supplied = Ivt = 5 $\times$ 6 $\times$ 300
But since electrical energy supplied = heat gained by the liquid,
=> 5 $\times$ 6 $\times$ 300 = 0.2 $\times$ c $\times$ 30,
=> c = $\frac{5 \times 6 \times 300}{0.2 \times 30}$ = 1500.
Therefore the specific heat capacity of the liquid = 1500J/kg^{0}c.

(Q11) A piece of metal of specific heat capacity 500J/kg^{0}k and mass 400g, is placed in an oven and then allowed to attain a steady temperature. It is then transferred into a calorimeter containing 1000g of water at 30^{0}c. The thermal capacity of the calorimeter and the stirrer is 105J/k. If the final temperature of the mixture is 35^{0}c, determine the temperature within the oven (i.e. the temperature of the oven).

[The specific heat capacity of water = 4200J/kg^{0}c].

N/B: 500J/kg^{0}c is the same as 500J/kg^{0}k.

- Also 105J/^{0}k is the same as 105J/^{0}c.

Soln:

Let θ = the temperature of the oven. Then the temperature obtained by the metal in the oven is also = θ.

Heat lost by the metal = heat gained by the water + heat gained by the calorimeter and the stirrer. Also the final temperature of the mixture = 35^{0}c.

<u>Metal:</u>

Mass of metal = 400g = 0.4kg.

Specific heat capacity = c = 500J/kg^{0}c.

Initial temperature = θ.

Final temperature = 35^{0}c.

Since the metal will lose heat to the water, the calorimeter, and the stirrer, then its initial temperature will be higher than its final one (i.e 35^0c).

Therefore change in temperature of metal = θ - 35.

Heat lost by the metal = m $\times$ c $\times$ (θ - 35) = 0.4 $\times$ 500 $\times$ (θ - 35)= 200 (θ - 35).

Water:

Mass = 1000g = 1kg.

Specific heat capacity = 4200J/kg^{0}k

Initial temperature = 30^0c.

Final temperature = 35^0c.

Change in temperature = $\triangle\theta$ = 35 – 30 = 5^0c.

Heat gained by water = m $\times$ c $\times$ $\triangle\theta$ = 1 $\times$ 4200 $\times$ 5 = 21000J.

N/B:

Since the water is within the calorimeter, then the initial temperature of the two will be the same.

- The stirrer will also be at the same temperature.

Calorimeter/ stirrer:

Initial temperature = 30^0c.

Final temperature = 35^0c.

Change in temperature = 35 – 30 = 5^0c.

Thermal capacity of calorimeter/ stirrer = 105J/k.

Heat gained by calorimeter and stirrer = Thermal capacity $\times$ change in temperature = 105 $\times$ 5 = 525J.

But heat lost by metal = heat gained by calorimeter and stirrer + heat gained by water.

=> $200(\theta - 35) = 525 + 21000$,

=> $200(\theta - 35) = 21525$,

=> $200\theta - 7000 = 21525$,

=> $200\theta = 21525 + 7000$,

=> $200\theta = 28525$

=> $\theta = \frac{28525}{200} = 143^0$c.

(Q12) A piece of metal has a thermal capacity of 46.2J/^{0}c, and a mass of 0.10kg. When it is placed in a refrigerator, it cools from 20^0c to 0^0c in 10seconds. Determine

(I) the rate of loss of heat from the metal.
(II) its specific heat capacity.

Soln:

(I) Mass of metal = 0.10kg.

Initial temperature of metal = 20^0c.

Final temperature of metal = $0\ ^0$c.

Change in temperature of the metal = $20^0 – 0^0 = 20^0$c.

Heat lost by the metal = Thermal capacity $\times$ change in temperature = 46.2×20 = 924J.

Amount of heat lost = 924J.

Time taken in seconds for this heat to be lost = 10 seconds.

Rate of heat lost = $\frac{amount\ of\ heat\ lost}{time\ taken\ in\ seconds}$

= $\frac{924}{10} = 92.4$W.

(II) Since thermal capacity = mass x specific heat capacity,

=> specific heat capacity = $\frac{thermal\ capacity}{mass} = \frac{46.2}{0.10}$

= 462J/kg^{0}c.

(Q13) A piece of copper of mass 120g is heated in an enclosure to a temperature of 125^{0}c. It was then taken out of the enclosure and held in the air for half a minute, and then carefully dropped into a copper calorimeter of mass 105g containing 200g of water at 20^{0}c. If the temperature of the water rises to 25^{0}c, calculate the rate at which heat is being lost from the piece of copper when it was held in the air. [Specified heat capacity of water = 4200Jkg^{-1} ^{0}C^{-1} and that of copper, = 400Jkg^{-10}c^{-1}].

Soln:

For the copper mass:

Mass = 120g = 0.12kg.

Initial temperature = 125^{0}c.

Final temperature = 25^{0}c.

Change in temperature = $\triangle\theta$ = 125 – 25 = 100^{0}c.

Specific heat capacity = c = 400Jkg^{-1} ^{0}c^{-1}.

Amount of heat expected to have been lost by this copper masss to the air, the water and the calorimeter when it cools from 125^{0}c to 25^{0}c = m $\times$ c $\times\triangle\theta$ = 0.12 $\times$ 400 $\times$(125 – 25) = 0.12 $\times$ 400 $\times$ 100 = 4800J.

N/B: - It must be noted that since the hot copper mass was held in the air for sometimes, then part of the heat lost willl be lost to the air.

For copper calorimeter:

Mass = m = 105g = 0.105kg.

Initial temperature = 20^{0}c.

Final temperature = 25^{0}c.

$\triangle\theta = 25 - 20 = 5^{0c}$

Specific heat capacity = 400$Jkg^{-1}\,{}^0C^{-1}$.

Heat gained by the copper calorimeter = $m \times c \times \triangle\theta$

= $0.105 \times 400 \times (25 - 20)$

= $0.105 \times 400 \times 5$ = 210J.

<u>For the water in the calorimeter:</u>

Mass = m = 200g = 0.2kg.

Initial temperature = 20^0c

Final temperature = 25^0c.

Change in temperature = $\triangle\theta$= 25 – 20 = 5^0c.

Specific heat capacity = 4200$Jkg^{-1}\,{}^0c^{-1}$.

Heat gained by the water = $m \times c \times \triangle\theta = 0.2 \times 4200 \times 5$ = 4200J.

But the heat lost by the copper mass = heat gained by the air + heat gained by the calorimeter + heat gained by the water.

=> 4800J = heat gained by the air + 210J + 4200J,

=> 4800J = heat gained by the air + 4410J, => 4800J – 4410J = heat gained by the air, => 390J = heat lost by the copper to the air.

Amount of heat lost = 390J.

Time taken for this heat to be lost = 30 seconds (since the copper mass was held in the air for 30 seconds).

Rate of heat lost = $\frac{390}{30} = 13$J/s.

(Q14) A copper calorimeter is put on a table in the laboratory and hot water is poured into it until it is two third full. State two possible means by which the water may lose heat. Explaine how you would minimise the heat loss by these means.

Soln:

The copper calorimeter and its content can lose heat by radiation, from the hot surface of the calorimeter and by convection, from the surface of the hot water.

Radiation can be minimised by highly polishing the outer surface of the calorimeter.

- Convection can be minimised by covering the calorimeter with a material of poor thermal conductivity such as cotton.

(Q15) A waterfall is 10m high and the difference in temperature between the water at the top and that at the bottom is 0.24^0C. Obtain a value for the specific heat capacity of water in J/kg^{0}C. Explain the steps in your calculations and mention any assumptions made.

Soln:

Assume that the same volume of water of mass M, will fall from the top of the falls and enter the water at the bottom.

Then the energy possessed by this mass of water at the top part of the waterfall = potential energy = mgh.

At the bottom of falls, the temperature of the same mass or volume of water under considereation has changed by 0.24^0C., => $\triangle\theta$ = 0.24^0C. The energy possessed by the water at the bottom of the falls which is in the form of heat energy = m $\times$ c $\times \triangle\theta$.

Now since energy possessed by this mass at the top of the falls = the energy possessed at the bottom of the falls by the same mass of water,

then m x g $\times$ h = m $\times$ c $\times \triangle\theta$

=> gh = c $\times \triangle\theta$,

=> C = $\frac{gh}{\triangle\theta}$ = $\frac{10 \times 100}{0.24} = 4166$

= 4200J/kg^{0}C approx.

Assumption made:

Energy is always conserved when it undergoes transformation.

The determination of the specific heat capacity:

This can be done by using two methods, which are:

(I) The method of mixtures.

(II) The electrical method.

The method of mixtures:

(1) A metal of mass M_m is taken, and hanged on a thread.
(2) It is then suspended in boiling water.
(3) The temperature of the boiling water is then determined using a thermometer, and let this temperature = θ_b.
(4) A weighed mass of water at room temperature is taken, and put into a double walled calorimeter.
(5) Let the mass of the water be M_w, the room temperature be θ_r and the mass of the calorimeter be M_c.
(6) The warmed metal is then quickly transferred from the boiling water into the calorimeter.
(7) As the water is continuously stirred, the rise in temperature is continuously monitored.
(8) The final steady temperature is noted and let this be θ_S.

Theory:

(1) If no heat is lost during the process, then the heat lost by the body in cooling from θ_b to θ_S = the heat gained by the calorimeter and its content in warming from θ_r to θ_S.
(2) If C_m, C_W and C_C are the specific heat capacities of the metal, water and the calorimeter respectively, then $M_mC_m(\theta_b - \theta_S) = M_WC_W(\theta_S - \theta_r) + M_CC_C((\theta_S - \theta_r)$.

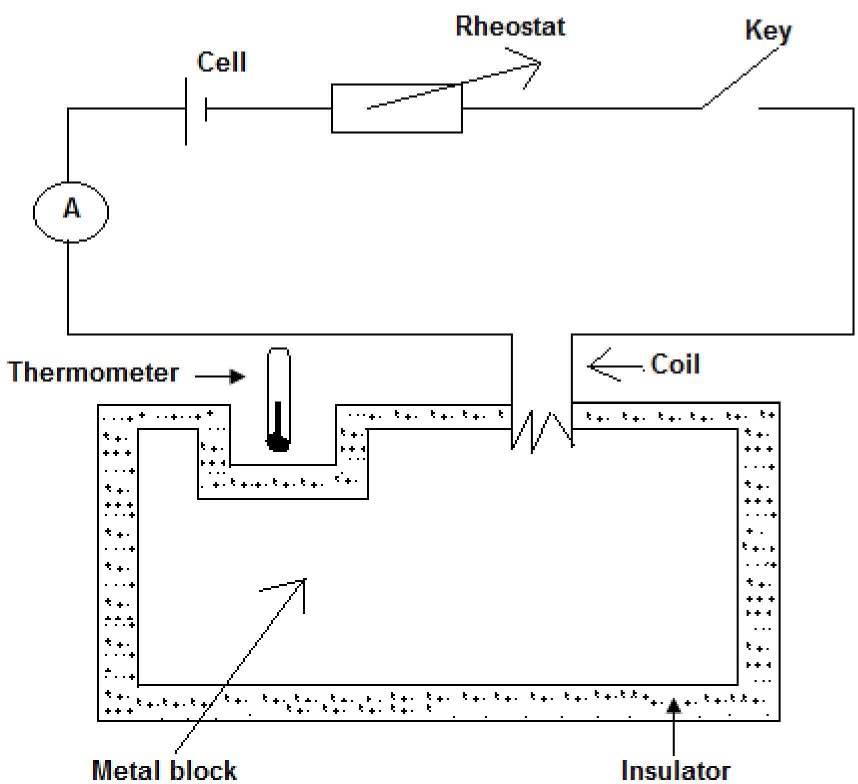
=> $C_M = \frac{M_W C_W(\theta_s - \theta\text{r}) + M_C C_C(\theta_S - \theta_r)}{M_m(\theta_b - \theta_S)}$.

(3) Since all the parameters in the above equation are known, then C_M can be calculated.

Precautions:

- In performing such an experiment, these precautionary measures must be taken.
  (1) The hot metal must be quickly transferred into the calorimeter and its content, in order to avoid the heat lost by radiation.
  (2) The water within the calorimeter which contains the hot metal, must be stirred continuously in order to obtain a uniform temperature.
  (3) The calorimeter must be well polished, to minimize the heat lost by radiation.
  (4) The calorimeter must be surrounded by layers of lagging materials such as cotton wool, so as to reduce heat losses by conduction and convection.

The electrical method:



Procedure:

(1) A metal block with at least two holes drilled in it, is placed in a felt jacket which covers it completely.

(2) The initial temperatureθ, of the block is measured with a thermometer.
(3) A heating coil is inserted and a known current I, is passed through the block for a known time t.
(4) The final temperature θ_2 of the block is then measured.

Theory:

(1) Neglecting heat losses, then the heat supplied by the electric coil = the heat gained by the metal block.
(2) The heat supplied by the heating coil in time t = vit, where v = the p.d across the coil, I = current in amperes and t = time in seconds.
(3) The heat gained by the block = M × c × ($\theta_2 - \theta_1$), where c = the specific heat capacity of the metal.
⇨ vit = m × c × ($\theta_2 - \theta_1$),
=> $c = \frac{Vit}{M(\theta_2 - \theta_1)}$

(4) The experiment is repeated several times, and the average value of c is computed.

Precautions:

(1) The stop clock should be started at the same time as the switch or key is closed.
(2) A small amount of oil, must be added to the thermometer hole before the thermometer is inserted, to ensure that good thermal contact between the block and the thermometer is achieved.
(3) The block should be well lagged, so as to reduce the lost of heat by conduction and convection.
(4) The block should be polished to reduce the heat lost by radiation, since shiny surfaces are bad radiators of heat.

Questions:

(1) Differentiate between the specific heat capacity and the heat capacity of a given mass of water.

Ans: - The specific heat capacity is the amount of heat needed, to raise the temperature of 1kg of water by 1^0c.

The heat capacity is the amount of heat needed, to raise the temperature of the whole mass of the water by 1^0c.

(2) The specific heat capacity of a 10kg metal is 320J/kg^{0}c. Determine its heat capacity.

Ans: 3200J/k or 3.2kJ/k.

(3) A substance has a mass of 700g and a specific heat capacity of 225J/kg^{0}c. What is its heat capacity?

Ans: 158J/k.

(4) A 5.7kg metal of specific heat capacity 28Jkg^{-1} had it temperature raised by 13^0c. Calculate the amount of heat energy it gains in kilojoules.

Ans: 2.075kJ.

(5) A substance of mass 2000g, has a specific heat capacity of 45J/kg^{0}c. If its temperature is increased from 10^0c to 22^0c, determine the amount of heat gained by the substance.

Ans: 1080J.

(6) The heat capacity of an object is 440J/^{0}c. If its temperature increases by 20^0c, find the amount of heat that it gains.
Ans: 8800J or 8.8kj.

(7) By increasing the temperature of a body from 4^0C to 9^0C, the amount of heat that it gains is 1050J. Find its heat capacity.
Ans: 210J/^{0}C.

(8) By decreasing the temperature of a substance from 18^0C to 10^{0c}, the amount of heat lost is 4000J. What is the specific heat capacity of this substance, if the mass of the substance is 50000g?
Ans: $10J/kg^0C$.

(9) The temperature of a body whose heat capacity is $200J/^0C$ dropped or decreased. If 400J of heat energy was lost as a result of that, what was the drop in temperature?
Ans: 2^0C.

(10) A student took 10,000g of a material, whose specific heat capacity is $7Jkg^{-1}\,^0C^{-1}$.If he provided it with 350J of heat energy, what will be the rise in the temperature of the material?
Ans: 5^0C.

(11) Determine the final temperature of the mixture, if 400g of water at a temperature of 80^0C, is added to 200g of cold water whose temperature is 25^0C and well stirred. [Specific heat capacity of water = $4200J/kg^0C$].
Ans: 61.7^0C.

(12) A chemist, who only had 500g of copper metal left in his laboratory, took half of it and heated it to a temperature of 100^0C. He then placed 120g of a substance whose specific heat capacity is $2400J/kg^0C$, and whose temperature was 10^0c into a 10g aluminum can, and quickly dropped the heated copper into it. Determine the final temperature of the mixture, after stirring.
Ans: 33^0C.

(13) A science tutor who wanted to determine the specific heat capacity of a metal, took 0.5kg of it and placed it into a gas oven in order to heat it to a temperature of 100^0C. He then placed it quickly into a 0.2kg of water, whose temperature was 15^0C. If the final temperate of the mixture was 20^0c, calculate the specific heat capacity of the metal. [Specific heat capacity of water = $4200J/kg^0C$].
Ans: $105J/kg^0C$.

Q14 A 0.1kg brass statue whose temperature was 100^0, was placed into an aluminum can of mass 0.5kg, which contained 150g of paraffin whose temperature was 11^0C. If the final temperature of the mixture was 20^0C, calculate the specific heat capacity of paraffin, given that the heat capacity of aluminum is negligible. [The specific heat

capacity of brass = 0.38J/kg^{0}C and that of aluminum is 900J/kg^{0}C].
Ans: 2.3J/kg^{0}C.

(15) John took a 60g copper calorimeter and placed into it 50g of water, whose temperature was 10^{0}C. He then heated a piece of solid copper of mass 40g to a temperature of 200^{0}C, and quickly placed it into the water. Given the specific heat capacities of copper and water to be 0.4J/g^{0}C and 4.2J/g^{0}c respectively, what was the final steady temperature of the mixture after stirring?
Ans 24^{0}c.

(16) 0.2kg of a certain liquid whose specific heat capacity is 1500J/kg^{0}C, is to be heated by an electric heater from an initial temperature of 21^{0}c to a final one of 51^{0c}. If the voltage to be used is 6v and the current passed is expected to be 5A, determine the time in seconds that the liquid must be heated.
Ans: 300 seconds.

(17) (a) With the aid of a diagram, explain how the specific heat capacity of a metal can be determined, through electrical means.

(b) Briefly explain why the body produces sweat when it is hot.

(18) A science student added 200g of hot water whose temperature was 80^{0}C, to 300g of cold water whose temperature was 10^{0}C. Determine the final steady temperature of the mixture. [S.H.C. of water = 4200J/kg^{0}C].
Ans: 38^{0}c.

(19) A certain amount of a liquid whose heat capacity is 420J/^{0}c, and whose temperature was 90^{0}c was added to a second liquid whose temperature was 5^{0}c, and whose specific heat capacity was 200J/kg^{0}C. If the final temperature of the mixture was 20^{0}c, what was the mass of the second liquid?
Ans: 9.8kg.

(20) A copper coil of mass 20g and whose temperature was 88^{0}C is placed into a copper calorimeter of mass 30g. If this calorimeter contains 20g of water at a temperature of 10^{0}C, determine the final steady temperature of the mixture after stirring. [Specific heat capacity of copper = 0.4J/g^{0}C, and that of water = 4.2J/g^{0}C].
Ans: 16^{0}C.

(21) 400g of a substance was heated from a temperature of 60^{0c} to that of 90^{0}c, by a current of 10A whose voltage was 8v for 2 minutes. Calculate

(a) the specific heat capacity of the substance. Ans: $0.8J/g^{0}C$.

(b) the thermal capacity of the substance. Ans: $320J/^{0}C$.