FORM 4 SPM PHYSICS SHORTHAND NOTES
Chapter 4 Heat
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4.1 Thermal Equilibrium

To do well in this chapter, you must first understand the difference between temperature and heat. **Temperature** is a numerical measure of hot and cold. It is related to the **average kinetic energy of individual atoms**. The SI unit for temperature is in **Kelvin**. Heat is a form of energy (not a force). Its SI unit is in **Joules** (similar to kinetic and gravitational potential energy). Two facts about heat:

1) Heat transfers at a faster rate from a hot (higher temperature) to a cold object (lower temperature).
2) Heat transfers slowly from a cold to a hot object.

Thermal equilibrium is achieved when **the *heat transfer rates* from 2 objects are *equal*,** meaning the net heat transfer is 0 Joules. Two things happen when *thermal equilibrium* is achieved:

1) The temperatures of all objects are equal.
2) No net gain or loss of energy between the objects.

Which direction does heat transfer to if

A has a higher temperature than B?

____

A has a smaller mass but higher temperature than B?

____

A has a bigger mass but the same temperature as B?

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A has a greater heat energy but the same temperature as B?

____

An application of thermal equilibrium can be seen in the thermometer. A thermometer is an instrument used to measure the temperature. Mercury is usually used because it is

1) Opaque: Easier to see.
2) Expands and contracts uniformly: Can use scales.
3) Does not stick to the glass: Can use scales.
4) Good thermal conductivity: Achieves thermal equilibrium at a faster rate.

The sensitivity of a mercury thermometer can be increased by using

1) Smaller/ bigger bulb. Increases surface area for heat conduction.
2) Glass/ wood bulb. Lower specific heat capacity.
3) Narrower/ wider capillary tube. Mercury does not have to expand as much
for a small change in temperature.

Steps to calibrate a thermometer

1) Placed in ice cube
2) Mark 0ºC
3) Place above steam
4) Mark 100ºC
5) Divide 100 equal divisions

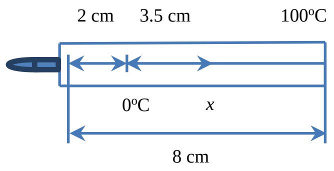
$$\theta = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100C$$

where

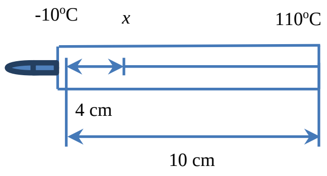
l_θ
$= length\ of\ mercury\ column\ at\ required\ temperature$

$l_0 = length\ of\ mercury\ column\ at\ lower\ fixed\ point$

l_{100}
$= length\ of\ mercury\ column\ at\ upper\ fixed\ point$



Find the temperature of *x*. *Hint: use the formula*



Find the temperature of *x*. *Hint: use the formula*

4.2 Specific Heat Capacity

Heat capacity is defined as **the heat required to change the temperature by 1ºC or 1K.**

A lower heat capacity means the object heats up easier. While a higher heat capacity means an object heats slower. You should not confuse temperature with heat. A spoon in hot glass of water may have the same temperature when thermal equilibrium is achieved. However, the amount of heat energy of the hot water in the cup is larger than that on the spoon because the mass of the water is a lot larger!

$$Heat\ Capacity = \frac{Thermal\ energy}{change\ in\ temperature} = \frac{Q}{\theta}$$

The units for heat capacity are J/celsius.

Note: In physics, every time you see the word specific, you can change it to per unit mass

Specific heat capacity is defined as **the amount of *heat* required to *change the temperature by 1ºC or 1K* for a mass of *1kg* of the substance.**

$$Specific\ Heat\ Capacity, c$$

$$= \frac{Thermal\ energy}{change\ in\ temperature\ per\ unit\ mass} = \frac{Q}{\theta m}$$

The units for specific heat capacity are **J/Celsius per kg.**

Find the specific heat capacity given 3kg of *x* with a temperature change from 28ºC to 63ºC assuming it was supplied with 94500J of heat.
Hint: 1) Identify m, C and θ
2) Which direction is heat transferring to?

A 1kW heater is used to heat 250g of water for 1 minute. The temperature of the water changes by 51ºC. Calculate the specific heat capacity of water. *Hint: Convert electrical power to heat energy.*

500g of copper @ 90ºC placed in 300g of water at 30ºC. Assume adiabatic find the final temperature of the water.
Hint:

1) *Identify which direction the heat transfer is*
1) *The water gains the heat loss from the copper.*

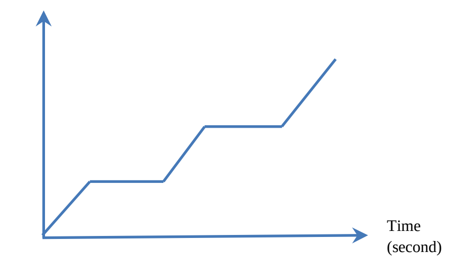
4.3 Specific Latent Heat

Latent heat is defined as **the thermal *energy absorbed or released* during *constant temperature*.**

As more heat is applied, the temperature stops rising and the heat energy breaks intermolecular forces.

Latent heat of fusion – *solid liquid*

Latent heat of vaporization – *liquid gas*



Amount of heat required to change 1kg of substance at constant temperature

$$Specific\ Latent\ Heat, l = \frac{heat}{per\ unit\ mass} = \frac{Q}{m}$$

The units for specific latent heat are **Joules per kg**

1) Specific latent heat of fusion is the *heat* required to change *1kg* of substance from *solid to liquid without changing the temperature*.
2) ______________________________________
____
____
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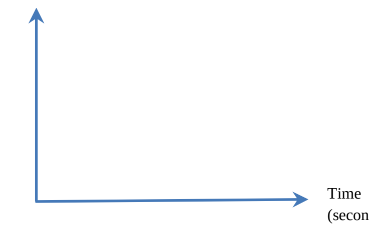
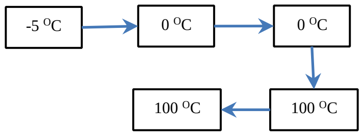
Do this in reverse from Boiling to freezing



Calculate the total heat to change 1kg of ice to steam. *Hint: The diagram below might help to visualize the problem.*



C_{water} = *4200* $Jkg^{-1}C^{o-1}$
C_{ice} = *2100* $Jkg^{-1}C^{o-1}$
Specific latent heat of fusion = 3.36×10^5 Jkg^{-1}
Specific latent heat of vaporization = 2.26×10^6 Jkg^{-1}

4.4 The 3 Gas Laws

1) Boyle's Law

Temperature is constant, $youressure \propto \frac{1}{Volume}$ for a fixed gas mass.

Remember that there must be a constant between two variables to be proportional (in this case, pressure and the inverse of volume).

$$P_1 = \frac{k}{V_1}$$

k is called the constant of proportionality (Imagine that k is the slope between the two variables). If the volume V_1 is changed to V_2, the P value must also change following the constant.

$$P_1V_1 = P_2V_2$$

Again rearranging

$$\frac{P_1}{P_2} = \frac{V_2}{V_1}$$

2) Charles Law

Pressure is constant, $volume \propto temperature$ for a fix mass of gas.

Important: Always use the units in Kelvin for temperature involving the 3 Laws.

To convert °C to K, always add 273:

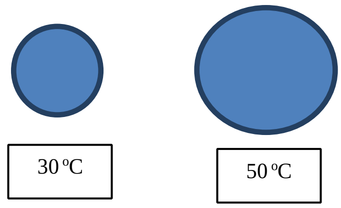
$$K = T \ in \ Celsius + 273$$

For example

0°C ⇨ 273 K
100°C ⇨ 373 K

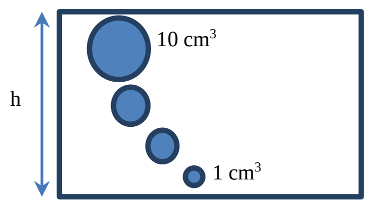
3) Pressure Law

Volume is constant, $pressure \propto temperature$ for a fix mass of gas



What is the final volume of the ball if its initial volume is 20 cm^3?

A tyre has air pressure 23 kPa when the temperature is 27°C. What is the pressure of the tyre if the temperature is increased to 57 °C?



Find the height of the aquarium, h if 1 atm = 10 m