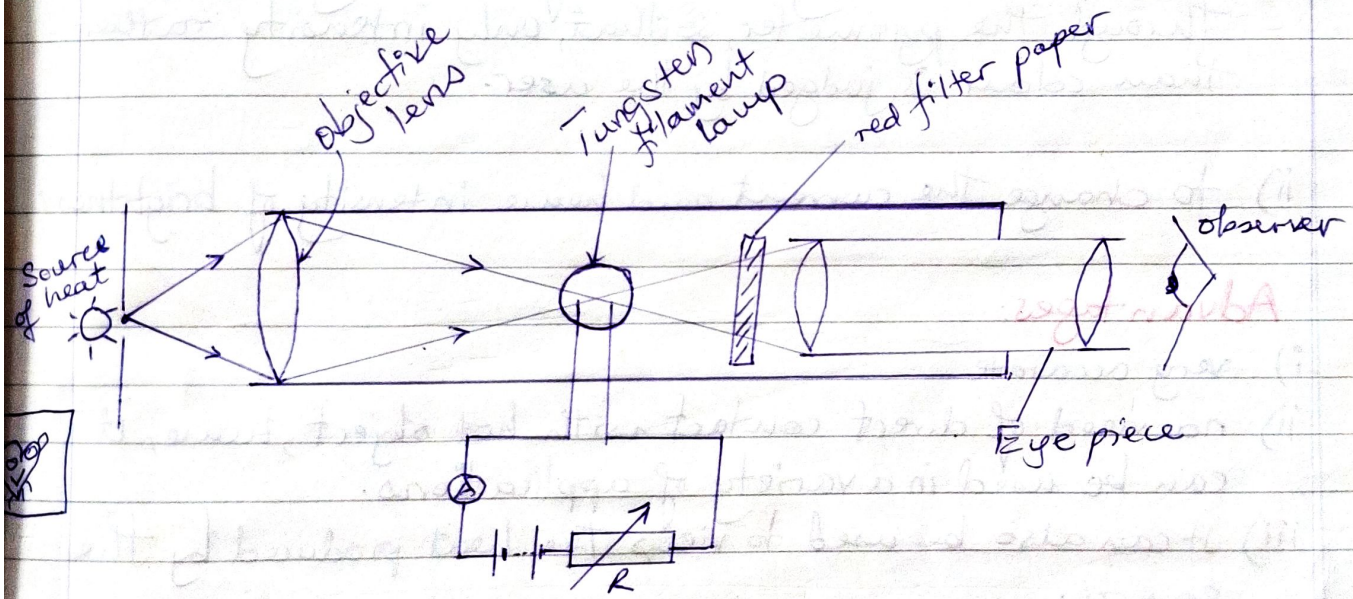
PYROMETRY

Pyrometers use the ~~radiation~~ wavelength of the radiation emitted by a hot body as their thermometric property.
The wavelengths of the radiations emitted depend on the temp. of the body
NB: Temps. above 1500°C are only measured using pyrometers.
There're two types of pyrometers:
i) Optical Radiation Pyrometer
ii) Total Radiation Pyrometer

OPTICAL RADIATION PYROMETER



How it works:
The source of heat (eg a furnace) is focussed using the objective lens such that its image lies in the same plane with that of the filament.
The observer looks thru the eye piece to observe the image of the small area of objective focused on the filament.
If the image of the source of heat is brighter than the filament, the filament appears dark on a bright background, implying that the filament is at a lower temp. than the hot body (source).
The temp. of the filament is adjusted using a rheostat until the image of the hot body and ~~that~~ the filament have the same brightness. At this

point, the temperature of the filament is equal to that of the hot body, and is read from the ammeter calibrated to read in degrees directly.

Students' home work.

1. State the functions of the:
   i) red filter
   ii) rheostat

Soln:

i) to help in narrowing the band of wavelength to pass through the pyrometer, so that, only intensity rather than colour is judged by the user.

ii) to change the current and hence intensity of brightness.

Advantages:

i) very accurate
ii) no need of direct contact with hot object, hence, it can be used in a variety of applications.
iii) It can also be used to view the heat produced by the source.

Disadvantages:

i) It can only be used in application with a minimum temperature of 700°C since measurements are based on light intensity.

ii) It is not useful for obtaining continuous values of temp at small intervals

Applications:

i) used to measure temp. of liquid metals or highly heated metals.
ii) can be used to measure furnace temperatures.

CALORIMETRY

Heat capacity, C; is the quantity of heat required to raise the temp. of a substance by 1K. SI unit is JK^{-1}.
If ΔQ is the quantity of heat, and $\Delta\theta$ is the change of temp, then $\Delta Q = C\Delta\theta \Rightarrow C = \frac{\Delta Q}{\Delta\theta}$ or $\frac{Q}{\Delta\theta}$

Specific heat capacity, c; is the quantity of heat required to raise the temp of a 1kg mass of a substance by 1K.
S.I unit is $JKg^{-1}K^{-1}$

Quantity of heat gained or lost by a substance depends on:
- mass of substance, m
- specific heat cap. (nature of substance), c
- change in the temp. $\Delta\theta$

$\therefore Q = mc\Delta\theta$, hence $c = \frac{Q}{m\Delta\theta}$

$$C = \frac{1}{m} \cdot C$$

$$\Rightarrow \boxed{C = mc}$$

Revision question:

1) The specific heat capacity of water is $4200\ JKg^{-1}K^{-1}$. What is meant by the above statement?

Soln:

means that 1kg of water gives out or takes in 4200J when its temp. changes by 1K.

2) Explain, in terms of specific heat capacity why water is used in a car radiator than any other liquid.

Ans.

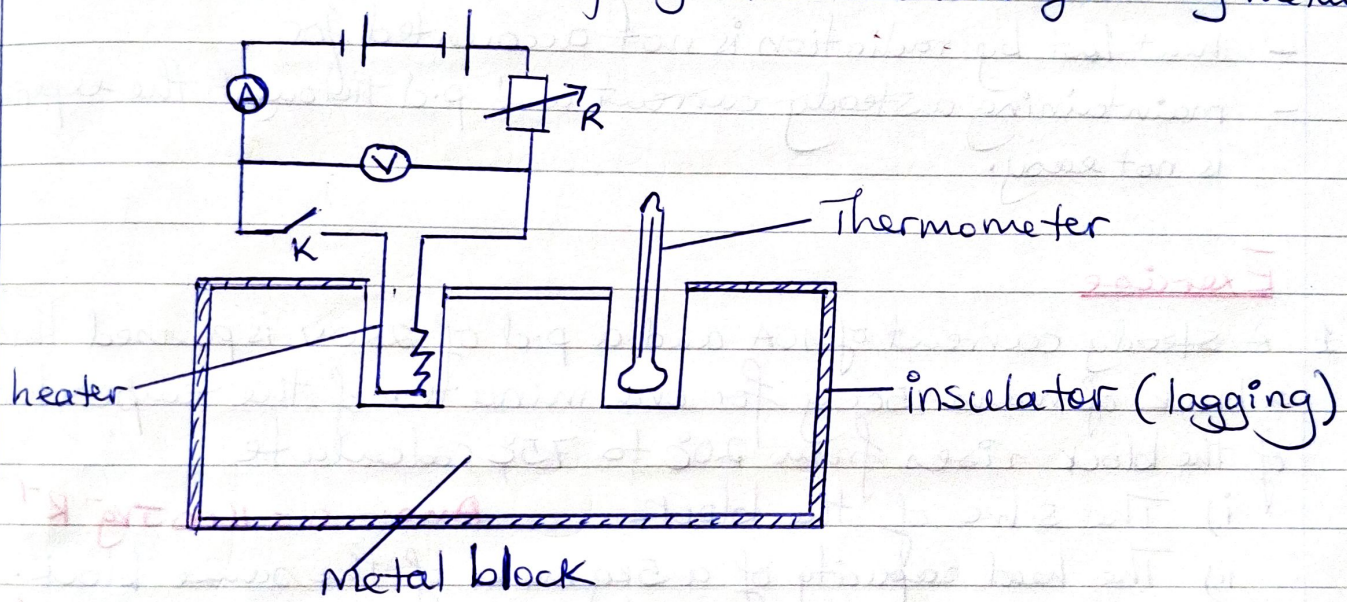
Water has a very high S.h.C ($4200\ JKg^{-1}K^{-1}$), hence a small amount of water can absorb alot of heat energy. Other liquids have low S.h.Cs, hence, large amounts of those liquids would be required to carry away the heat.

Specific heat Cap., c can be determined by various methods, namely:

i) Electrical method
ii) Continuous method
iii) Method of mixtures

Electrical Method to determine S.H.C of a solid

This method is suitable for good conductors of heat eg metals



- Two holes, for the heater and thermometer, are drilled into a solid of known mass, m.
- the solid, block of a metal, is wrapped with an insulator, the heater and thermometer are inserted in their respective holes.
- ~~switch K is closed~~ Temp. of the solid, θ_1 is measured before heating
- switch K is closed and stop clock started.
- A steady current I and p.d V will be passed through the heater for a time t.
- the final temp. θ_2 of the block after a time, t is recorded.

Assuming there's no heat loss to the surroundings;

heat supplied by heater = heat gained by solid

$$V \cdot I \cdot t = mc\Delta\theta \quad ; \quad \Delta\theta = \theta_2 - \theta_1$$

$$\therefore c = \frac{V \cdot I \cdot t}{m(\theta_2 - \theta_1)}$$

Advantages:
- easy to carry out

Disadvantages
- not accurate
- not good for bad conductors of heat, because heat distribution will not be uniform.
- heat lost by radiation is not accounted for.
- maintaining a steady current and p.d throught the experiment is not easy.

Exercise

1. A steady current of 10A and a p.d of 220V is passed through a block of mass 1500g for one minute. If the temperature of the block rises from 20°C to 75°C calculate
   i) The s.h.c of the block Ans: $c = 1600 Jkg^{-1}K^{-1}$
   ii) The heat capacity of a 5kg mass of the same block.
   Ans: $8000 JK^{-1}$

2. If a mass of a body 8kg is heated for 10 minutes, with a voltmeter and ammeter readings 12V and 2.5A respectively. Given that the temp. rise produced is 20°C, find:
   i) power rating of the heater 30W
   ii) energy received by the metal 18,000J
   iii) The specific heat cap. of the metal. $112.5 Jkg^{-1}K^{-1}$
   iv) State the assumption made. no heat was lost to surroundings

Precautions to reduce heat losses:
i) There should be thermal contact between the thermometer and the drilled hole. This is achieved by adding a small amount of oil in the hole before inserting the thermometer
ii) The solid is lagged to reduce heat loss by conduction
iii) the metal block is polished to reduce heat loss by radiation.

Sources of error in the above experiment:

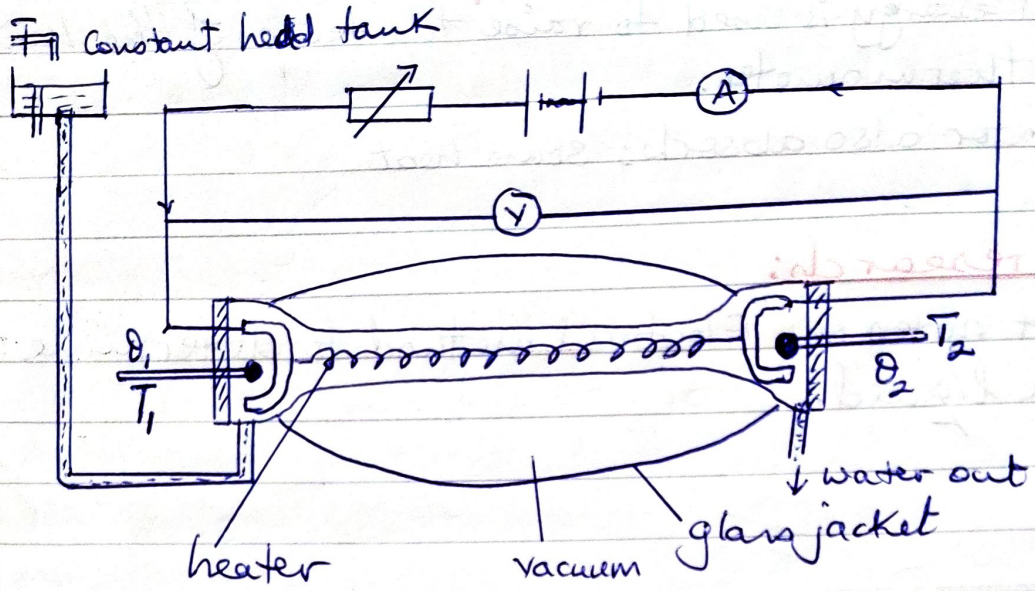
i) Some heat energy is used to raise the temp. of the heater and the thermometer.

ii) The insulator also absorbs some heat

Students' research:

Make short notes on; Electrical method to determine the S.h.c of a liquid.

CONTINUOUS FLOW METHOD



- The liquid whose specific h.c is to be determined is continuously passed through the apparatus at a constant rate.
- the heater is then switched on and the experiment is left to stand until steady states are reached, ie when the inflow temp. θ_1 and outflow temp. θ_2 are constant. At this moment, no heat is taken in to heat the apparatus, ∴ all heat supplied raises the temp. of the liquid.
- temps. θ_1 and θ_2 are read from the thermometers T_1 and T_2 respectively, and noted.
- the current I_1 and voltage V_1 are read off the ammeter A and voltmeter V, and noted.
- the mass of liquid which flows per sec is found, recorded as m_1

∴ Power supplied = Power gained + Power lost to the surroundings
by heater by liquid

$$I_1V_1 = m_1C(\theta_2-\theta_1) + H \quad ----(1)$$

- to eliminate the power lost to the surrounding, the rate of liquid flow is adjusted, to a new value m_2 at the same temps. θ_1 and θ_2
- new values of I_2 and V_2 are noted.

Similarly; $I_2V_2 = m_2C(\theta_2-\theta_1) + H \quad ---(2)$

Eqn (2) minus (1) gives

$$I_2V_2 - I_1V_1 = m_2C(\theta_2-\theta_1) - m_1C(\theta_2-\theta_1)$$

$\therefore c = \frac{I_2V_2 - I_1V_1}{(m_2 - m_1)(\theta_2 - \theta_1)}$ where c is the s.h.c of the liquid.

Advantages of the continuous flow method

i) Heat capacity of the apparatus is not required
ii) heat losses are accounted for quantitatively due to heat loss
iii) method is very accurate since errors are eliminated by repeating experiment, hence no ~~cot~~ cooling correction is required.
iv) readings are taken out at steady state, ∴ can be measured accurately.

Disadvantages

i) requires a liquid available in large quantities.
ii) can only be used for liquids not solids.
iii) cannot be used to determine the s.h.c of volatile liquids.

Worked Examples

1. In a continuous flow method, the inflow and outflow temps were maintained at 25.2°C and 26.51°C respectively. For a p.d of 12.0V and current 1.5A, the rate of flow was 90g per minute; with 16.0V and 2.0A, the rate of flow was 310g per minute. Find the:
   i) specific h.c of the liquid
   ii) power lost to the surroundings.

Soln:

$18 = 1.965 \times 10^{-3} c + H$ ---①

$32 = 6.7683 \times 10^{-3} c + H$ ---②

Eqn ② − ①

$14 = 4.8033 \times 10^{-3} c$

$\therefore c = 2914.7 \text{ Jkg}^{-1}\text{K}^{-1}$

Subst. for c in eqn ①:

$H = 12.27 \text{W}$.

Students should show the full working (solution) in their notes.

2. In a continuous flow experiment, a steady difference of temp. of 1.5°C is maintained when the rate of liquid flow is 0.045 kg/s and the rate of electrical heating is 60.5W when the liquid flow rate is reduced to 0.015 kg/s, 36.5W are necessary to maintain the same temp. difference. Calculate the;

i) S.h.c of the liquid

ii) Rate at which heat is lost to the surroundings.

Soln:

$60.5 = 0.0675c + H$ ---①

$36.5 = 0.0225c + H$ ---②

$\therefore c = \frac{24}{0.045}$

$= 533.3 \text{ J kg}^{-1} \text{K}^{-1}$

Subst. c into eqn ②;

$H = 24.5\text{W}.$