S.5 HEAT NOTES TO COPY DURING MINI HOLIDAY-2020

Advantages of the electrical resistance thermometer

1) The single advantage of the electrical resistance thermometer is that is accurate. This is so because it is possible to measure resistance accurately.
2) They can be used over a fairly wide range of temperature.
3) It is used to measure steady temperatures.

Disadvantages of the electrical resistance thermometer

1) A long time is needed for the thermometer to assume the temperature it is required to measure owing to the large heat capacity. This means that a long time is needed for making an observation.
2) The thermometer cannot be used to measure temperature at a point.

Note. When calibrated against constant volume thermometers the resistance R of platinum is found to vary with Celsius thermometer θ according to

$$R_Q = R_0\left(1+\alpha\theta+\beta\theta^2\right)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where R_0 is the resistance of the platinum at 0^0c and α and β are constants. The values of R_0, α and β for a given platinum resistance thermometer can be found by measuring its resistance at the ice point, steam point and boiling point of sulphur and inserting the values into equation (1).

Constant volume gas thermometer.

(Leave 20 lines for diagram)

A simple form of a constant volume gas thermometer is shown above.

The thermometer property is the pressure of the gas

The bulb is immersed in an ice – water mixture. Time is allowed for the air inside the bulb to assume the temperature of the bath. Tube C is moved downwards to bring the mercury level in the left hand cm to the constant volume mark.

The difference, h_0 in the mercury levels in the two arms is measured.

- Time is allowed for the air in the bulb to attain the temperature in the bath
- Tube C is allowed to bring the mercury in the left hand side to the constant volume mark. The difference h_{100} between the mercury levels is measured.
- The bulb is then immersed in the system whose temperature is required.
- The difference in mercury levels, h_θ is determined as above
- The unknown temperature

$$\theta = 100\left(\frac{h_\theta - h_0}{h_{100} - h_0}\right)\ {}^0c$$

In a constant – volume gas thermometer there are a no. of source of error

These include.

i. The temperature of the gas in the 'dead space' is different from that of the gas in the bulb.
ii. Thermal expansion of the bulb.
iii. Capillary effects at the mercury surfaces.

For accurate work, H_2 or Helium or N_2 gases are used. The gas thermometers are used as a standard to calibrate other more practical thermometers.

Disadvantages of the constant volume gas thermometers

Inaccuracies in measuring the heights.

1. They are bulky
2. They are slow to respond
3. They do not give direct reading.
4. Expensive to make.
5. Can not be used to measure temperatures at points, only temperature of the air surrounding the bulb.

Advantages

1. They have a wide range (-270^0C to 1500^0C).
2. They are accurate.
3. They are sensitive to any change in temperature.

Thermocouples

Suppose wires A and B of different materials are joined to make junctions 1 and 2 as shown

(Leave 15 lines for diagram)

If the temperature of the junction 1 is raised above that of junction 2, the galvanometer G shows a deflection implying that an emf has been generated. This emf is called a thermoelectric emf. The magnitude of the emf varies with the temperature difference between the two junctions. This is the basis of measurement of temperature using a thermocouple.

The test junction is immersed in a steam bath at one atmosphere pressure and the corresponding thermoelectric emf E_{100} measured.

The test junction is immersed in the system whose temperature is required. The corresponding thermoelectric emf E_θ is measured.

The unknown temperature, $\theta = 100\left(\frac{E_\theta}{E_{100}}\right)^0C$

Advantages of a thermocouple

1) Wide range of temperature i.e. $^-250^0$c to 1500^0c
2) It has a small heat capacity, hence it can be used to measure rapidly changing temperatures.
3) It can measure temperatures at a point.
4) Thermocouples can robust and compact. They are cheap and easy to construct.
5) It can be used for measuring low temperatures since the emf generated is small.

Disadvantages of thermocouple

Each thermocouple requires separate calibration.

Radiation pyrometers

A radiation pyrometer is an instrument used to measure the temperature of a body by the radiation that the body emits. They are best suited for measuring temperatures above 1000^0c . Radiation pyrometers are of two types;

i. Total radiation on pyrometer. These respond to both visible and infrared radiation
ii. Optical pyrometer- these respond only to visible radiation.

Optical pyrometer

A typical optical pyrometer is the disappearing filament pyrometer. This consists of a refracting telescope having a tungsten lamp filament at the focus of its objective as shown below.

(Leave 20 lines for diagram)

The observer looks through the red filter F at the filament against a background formed by the image of a small area of the body. If the image of the hot body is brighter than the filament, the filament will appear dark on a bright background. If the filament appears bright on the dark background i.e. hot body is then less bright than the filament. Current through the filament is adjusted until the filament "disappears". The ammeter A, calibrated to read temperature, will give the temperature of the hot body. The range of pyrometer is up to 300^0C.

(Leave one blank page for examples and total radiation pyrometer)

SPECIFIC HEAT CAPACITY

Specific heat capacity is the amount of energy required to raise the temperature of 1kg mass of as body by 1k. Its unit is $Jkg^{-1}K^{-1}$.

The quantity mass times the specific heat of the substance is called the heat capacity. Its unit is JK^{-1}

Measurement of specific heat capacities

Using method of mixtures

(Leave 20 lines for diagram)

A calorimeter is weighted empty and its mass, m_c recorded.

The calorimeter is then half – filled with water and weighted again to determine the mass of water m_w added. The temperature θ_1 of the water and calorimeter is measured after thorough stirring.

The mass m_s of the specimen solid is determined. The specimen is heated to a temperature, θ_2. The specimen is then quickly transferred into the water in the calorimeter. The temperature θ_3 reached by the mixture is determined.

Continuous stirring during the mixture must be ensured.

Assuming that all heat lost by the specimen is gained by the calorimeter and the water, then

$$m_s c_s(\theta_2-\theta_3)=m_w c_w(\theta_3-\theta_1)+m_c c_c(\theta_3-\theta_1)$$

Where c_s= Specific heat capacity of the specimen,

c_w = Specific heat capacity of water,

c_c = Specific heat capacity of material of the calorimeter

Thus $c_s=\left(\dfrac{m_w c_w+m_c c_c}{m_s(\theta_2-\theta_3)}\right)(\theta_3-\theta_1)$

Precaution

- Ensure that the specimen does indeed reach the temperature θ_2
- The specimen must be transferred into the calorimeter as fast as possible but carefully so as to avoid splashing water out of the colorimeter.
- The colorimeter must be placed on insulating stands in a constant temperature jacket.
- The calorimeter must be highly polished on the outer surface and the jacket on the inner surface to reduce heat loss by radiation.
- The lid reduces heat law by convection.
- Stirring while the temperature of the mixture is raising must be ensured.

Cooling correction in the method of mixtures

In the method of mixtures in determining specific heat capacity, a hot body is placed in a liquid at lower temperature. Consequently, the temperature of the liquid rises above that of the surroundings. In the process, heat is lost to the surroundings. The observed final temperature is lower than it would have been if no heat had been lot to the surroundings.

(Leave 30 lines for a graph and its explanation)

Question: Why should a cooling not applicable for good conductors?

Obtaining a cooling correction for a poor conductor of heat:

A known man of water m_w is placed in a container of known mass m_c. The temperature θ_1 of water is recorded. A rubber bung is weighed and its man m_s recorded. The bung is placed in boiling water and left in for sufficiently long for it to attain the temperature θ_2 of the boiling water.

The rubber bung is removed from the boiling water, shaking off the water drops dinging to it and is quickly transferred into the calorimeter.

The temperature θ, of the mixture, is recorded every half minute. A graph of temperature θ against time is plotted.

(Leave 25 lines for a graph and its explanation)

Determination of specific heat capacity of a liquid by the continuous flow method.

(Leave 30 lines for a diagram)

In the figure above, P_1 and P_2 are platinum resistance thermometers. The rate of flow of liquid through the apparatus is adjusted to suitable value by raising or leveling the constant head apparatus. The electric circuits connected up. Time is allowed for the thermometers P_1 and P_2 to record steady temperatures $\theta_1$and θ_2 respectively, are then recorded.

Water is collected at the outlet in a previously weighed beaker for a measured time. The rate, m_1 of flow of water is recorded. The ammeter and voltmeter reading I_1 and V_1 respectively are recorded. The constant pressure head is raised to obtain a new rate of flow. The current flowing is adjusted so as to keep $(\theta_2 - \theta_1)$ constant. The ammeter and voltmeter reading I_2 and V_2 respectively are recorded. The new rate m_2 of the flow of water is measured.

In the first part of the experiment

$I_1V_1 = m_1c(\theta_2 - \theta_1) + h$…………………………………………… (i)

Where c is the specific heat capacity of liquid, h is the small rate of loss of heat to the surroundings.

In the 2nd part of the experience

$I_2V_2 = m_2c(\theta_2 - \theta_1) + h$……………………………………………….. (ii)

Note that the rate of loss of heat to the surroundings is the same in both experiments since the excess temperature above the surroundings is the same (See Newton's law of cooling later).

Hence; equation (i) – equation (ii)

$$c = \frac{I_1V_1 - I_2V_2}{(m_1 - m_2)(\theta_2 - \theta_1)}$$

Advantages of the method

1. The temperatures are measured are steady and therefore can be determined accurately by using platinum resistance thermometer.
3. The heat capacity of the apparatus does not have to be known.
4. According correction is eliminated by a repeat experiment.
5. Since temperatures are steady, small temperature differences can be used. Hence the method can be used to investigate the temperature dependence of the specific heat capacity of a liquid.

Disadvantage

1. A large quantity of liquid is required.
2. Only limited to liquid

Research work: Mechanical method of determining specific heat capacity of a solid

Disadvantages of mechanical method of determining SHC

- ✓ -May take a lot of time because a lot of work has to be done to produce a measurable amount of heat. this leads to a relatively greater value of cooling correction
- ✓ kinetic energy of the weights as they fall on the floor may not be accounted for
- ✓ work done against friction in the pulleys and bearings of the peddle wheels,
- ✓ Energy stored in the stretching of the strings may also not be accounted for

Question:

(i) State two reasons why the mechanical method of determining SHC of a substance may not be accurate (02 marks)

(ii) A copper cylinder is mounted along the axis of a wooden pulley of radius 12.5cm. The pulley rubs against the cylinder when it turns. When a steady force of 100N is applied tangentially to the pulley, the temperature of the cylinder rises by 8 degrees Celsius after the pulley has been turned through 40 revolutions. If the mass of the copper cylinder is 250g, calculate the SHC of copper. (4 marks) (Wakissha, 2017)

Questions

1. In a determination of the specific heat capacity of rubber, by the method of mixtures, this data was obtained

Mass of calorimeter = 44.70g.

Mass of water in the calorimeter = 70.33g

Initial temperature of the rubber stopper = 96.5°C.

The temperature of the mixture was read and recorded every minute and the following results were obtained

Time (mm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Temp. of the mixture	30.5	34.5	35.5	36.0	36.5	36.3	36.0	36.0	35.9	35.6	35.4

i) Plot a graph of temperature of the mixture versus time

ii) Use the graph to determine the cooling correction (0.6K)

iii) Calculate the specific heat capacity of the rubber ($1.28x10^3 Jkg^{-1}k^{-1}$)

(Specific heat capacity of water = 4.2×10^3 $JKg^{-1}k^{-1}$)

(Specific heat capacity of copper = $3.8x\ 10^2$ $JKg^{-1}K^{-1}$)

(Mass of rubber stopper = 27.05g).

1. A copper colorimeter of mass 0.30kg contains 0.50kg of water at a temperature of 15°C. A 0.56kg block of copper at a temperature of 100°C is dropped into the colorimeter and the temperature is observed to increase to 22.5°C. Find the specific heat capacity of copper.

$$m_c = 0.30kg, m_s = 0.56kg, c_c = 3.8x10^2 Jkg^{-1}K^{-1}, m_w = 0.50kg, \theta_2 = 100^0 C, c_w = 4.2x10^3 Jkg^{-1}K^{-1}$$
$$\theta_1 = 15^o C, \theta_3 = 225^o C$$
$$m_s c_s(\theta_2 - \theta_3) = m_w c_w(\theta_2 - \theta_1) + m_c c_c(\theta_2 - \theta_1)$$

$$c_s = \left(\frac{m_w c_w + m_c c_c}{m_s(\theta_2 - \theta_3)}\right)(\theta_3 - \theta_1)$$
$$c_s = \frac{(0.5x4.2x10^3 + 0.3x3.8x10^2)(225-15)}{0.56(100-225)} = 3.83x10^2 Jkg^{-1}K^{-1}$$

2. In a continuous flow experiment it was found that when the applied p.d was 12.0V, the current was 1.54A, the rate of flow of liquid of 50g per minute caused the temperature of the inflow to differ by 10°C with temperature of inflows. When the p.d was increased to 16.0V (the current of 1.6A) a rate of flow of 90.0g per minute was required to produce the same temperature difference as before. Find the specific heat capacity of the liquid and the rate of heat loss.

$$c=\frac{I_2V_2-I_1V_1}{(m_2-m_1)(\theta_2-\theta_1)}$$

In continuous flow colorimeter for measurement of specific heat capacity of a liquid, 3.6 x $10^{-3}m^3$ of liquid flow through the apparatus in 10 minutes. When electrical energy is supplied to the heating coil at the rate of 44W, a steady difference of 4K is obtained between the temperatures of the outflow and inflow. When the flow rate is increased to 4.8 x $10^{-3}m^3$ of liquid in 10 minutes, the electrical power required to maintain the temperature difference is 58W. Find the;

i) Specific heat capacity of the liquid (2187.5$JKg^{-1}K^{-1}$)

ii) Rate of loss of heat. (2W)

(Density of the liquid = 800kgm^{-3})

4d) An electric drill takes 300s to make a hole in a piece of brass of man 9.5kg and the average power delivered from the mains in 45w.

i) Calculate the amount of energy used in drilling the hole.

ii) If 80% of the energy supplied to the drill is used to raise the temperature of the brass. Calculate the average temperature rise. State any assumption made.

(S.H.C of brass = 390$JKg^{-1}K^{-1}$).

NEWTON'S LAW OF COOLING

The rate of loss of heat by a body is proportional to the excess temperature over the surrounding.

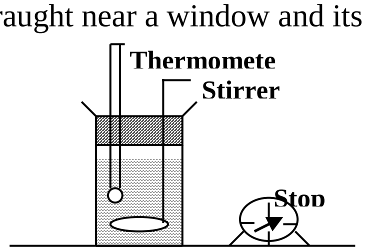
$$\frac{dQ}{dt}=(\theta-\theta_0)$$

Where θ = Temperature of body.

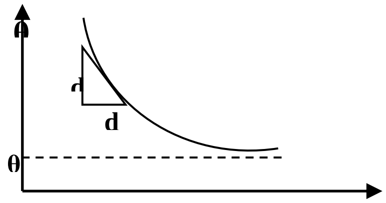
θ_o = temperature of surrounding

Experiment of verify Newton's law of cooling.

A colorimeter is filled with hot water initially at the temperature of about 90°C is placed in an air draught near a window and its temperature θ measured every ½ a minute.



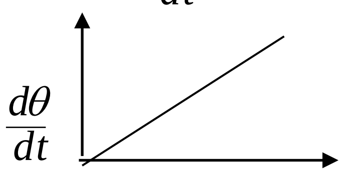
A graph of θ against time, t is plotted and is called a cooling cure.



Where θ_0 is the room/surrounding temperature

Tangents are drawn at different points of the curve and the slope of the tangents are the rate of fall of temperature, $\frac{d\theta}{dt}$ are determined

A graph of $\frac{d\theta}{dt}$ against excess temperature $(\theta - \theta_o)$ is plotted.



From the graph, we can say that $\frac{d\theta}{dt} \propto (\theta - \theta_0)$

$$\frac{dQ}{dt} = -\frac{mcd\theta}{dt}$$

where m = mass of liquid.

C is the specific heat capacity

$$\frac{dQ}{dt} \propto \frac{d\theta}{dt} \propto (\theta - \theta_0)$$

Hence $\frac{dQ}{dt} \propto (\theta - \theta_0)$

In general, the above relation is given by;

$$\frac{dQ}{dt} = ks(\theta - \theta_0)$$

where s = surface area of body losing heat, k is a constant which depends on the nature of the surface.

The mass of body is proportional to its volume.

The rate of heat loss however is proportional to surface area of the body. Therefore, the rate of fall at temperature is proportional to ratio of surface to volume of body.

For bodies of similar shape, the ratio of surface to volume is inversely proportional to any linear dimension

$$\frac{surface\,area}{Volume} \propto \frac{1}{linear\,dimension}$$

If the bodies have surfaces of similar nature, the rate of fall of temperature is inversely proportional to linear dimension. A small body cools faster than a large one. A tiny baby should be more thoroughly wrapped up than a grown man. In calorimeter, the fact that a small body cools faster than a larger one i.e the larger the specimen, the less serious is the rate of loss of heat, large calorimeter are normally used to reduce loss of heat to the surrounding.