

Mechanics lab.
First year students
Experiments' sheet
Second semester

Experiments:

1. Determination of surface tension of water by the capillary tube method
<https://newtonclasses.net/practicals-class-11-physics-surface-tension/>
<https://www.youtube.com/watch?v=YzG7po1F5hE>
https://www.usgs.gov/special-topic/water-science-school/science/surface-tension-and-water?qt-science_center_objects=0#qt-science_center_objects
2. Determination of the specific heat capacity of a solid
<https://www.youtube.com/watch?v=8gHFAL2990U>
3. Determination of the coefficient of viscosity of water by capillary tube
https://chem.libretexts.org/Courses/Oregon_Institute_of_Technology/OIT%3A_CHE_202_-_General_Chemistry_II/Unit_7%3A_Intermolecular_and_Intramolecular_Forces_in_Action/7.1%3A_Surface_Tension%2C_Viscosity%2C_and_Capillary_Action
4. Coefficient of linear expansion of a solid by Fizeau's method
<https://www.youtube.com/watch?v=TDnLbjd429M>
5. Gravitational & Elastic Potential Energy of a Spring
<https://www.youtube.com/watch?v=mGYUytLjJ8c>
<https://www.youtube.com/watch?v=0BObd3DsNFM>
6. Determination of the atmospheric Pressure using a Boyle's law apparatus
<https://www.youtube.com/watch?v=NRI-3jTizbg>
<http://galileo.phys.virginia.edu/classes/152.mf1i.spring02/Boyle.htm>

Note: Download source

<https://academics.su.edu.krd/bestoon.mustafa/teaching>

Experiment one

Determination of surface tension of water by rise in a capillary tube

Aim: To determine surface tension (γ) of tap water

Apparatus: Set of glass capillary tubes, travelling microscope, beaker, nitric acid, soda solution, distilled water, stand with clamp.

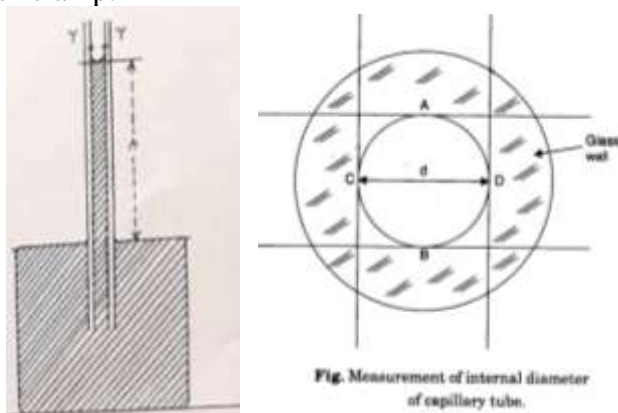


Fig. experiment setup

Method: The capillary tube and beaker are first thoroughly cleaned of dirt and grease by washing successively in caustic soda and nitric acid and finally rinsing thoroughly in distilled water. After cleaning, the inside of the beaker, and those parts of the capillary tubes to be immersed in the water, must not be touched by hand, to avoid further contamination by grease. The beaker is now filled to overflowing with distilled water (to facilitate readings of the rise by the travelling microscope), and one of the capillary tubes is thrust well down in the water to wet freely the inside of the tube. It is then raised slightly and clamped in a vertical position when the rise (h) is measured by the travelling microscope, by first focusing on the water level in the beaker and then on the lower portion of the meniscus. The tube is now removed from the water and clamped in a horizontal position. Two readings of the diameter in direction mutually at right angles are taken by the microscope, from which the mean radius of the tube is found. The experiment is repeated using capillary tubes of different diameters and an average value of surface tension is obtained. The temperature of the water is noted. Finally, use equation 1 to measure the value of γ .

Collect the data in table below:

Radius of capillary (r) in mm	Raise of water in capillary in mm	Surface tension in N/m	Average

Theory: The weight of the column of liquid (of density ρ) below the meniscus is supported by the upward forces of surface tension acting round the circumferences of the circle of contacts:

$$2\pi r\gamma = \pi r^2 h \rho g$$

Thus

$$\gamma = \frac{g\rho hr}{2}$$

$$\gamma = \frac{g\rho hd}{4} \dots\dots 1$$

With very fine capillary tubes, the meniscus surface may be considered to be hemispherical, and the weight of liquid above the lowest point of the meniscus is

$$(\pi r^3 - \frac{2}{3}\pi r^3) \rho = 1/3 \pi r^3 \rho g$$

Hence a more accurate equation of γ is:

$$2\pi r\gamma = \pi r^2 h \rho g + \frac{1}{2}\pi r^2 \rho g$$

$$\gamma = \frac{1}{2} \rho g r (h + \frac{r}{3})$$

$$\rho = 1000 \text{ kg m}^{-3},$$

$$g. 9.81 \text{ m/s}^2$$

Notes:

the above formula only applies to liquids which wet the glass such as water, aqueous solutions, alcohol and etc. for other liquids such as paraffine which have an angle of contact with the glass, only resolved parts $2\pi r\gamma \cos \theta$ of the surface tension forces act upwards and expression of equation 1 is modified to:

$$\gamma = \frac{2\rho hr}{2 \cos \theta}$$

If the capillary tube is not uniform it should be broken at the meniscus level and the mean radius of the section determined as before.

Experiment two

Determination of the specific heat capacity of a solid

Aim: To determine the specific heat capacity of a solid material.

Apparatus: Copper calorimeter with stirrer (of thick copper wire), double-walled enclosure with cold water between the walls, thermometer, stop watch, steam heater, piece of rubber (e.g. large rubber stopper).

Method: The rubber stopper is weighted and placed in the steam heater where it is left for a period of at least 30 min until its temperature reaches that of the steam. During this time, the calorimeter (with stirrer) is weighed empty, and about half full with water. The calorimeter and the container are placed on corks inside the constant-temperature enclosure, and the temperature of the water taken. The hot rubber stopper is now quickly transferred to the waiting calorimeter, and the stop watch started. Reading of the temperature are taken at minute interval, and are continued after the mixture has attained its highest temperature until the calorimeter and contents cool through about 5 °C. A temperature-time graph is now drawn which is corrected for radiation losses in the manner indicated so as to obtain the corrected final temperature of the mixture for use in the heat equation for calculating the specific heat.

Calculation and data collection

Mass of rubber stopper (**m**) = kg

Mass of calorimeter and stirrer (**w**) =kg

Mass of calorimeter and stirrer and water =kg

Weight of water (**W**) = Kg

Temperature of steam (**T'**) = °C

Temperature of cold water (**t**) = °C

Temperature of mixed (corrected) (**T**) = °C

Specific heat capacity of water = $4.185 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$

Specific heat capacity of copper = $0.381 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$

Heat lost by rubber (of specific heat capacity, **c**) = heat gained by calorimeter and contents,

i.e.

$$mc(T' - T) = (W \times 4.185 + w \times 0.318) \times 10^3 (T - t) \dots \text{Eq. 1}$$

Thus

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

Theory: For accurate calorimetry, a correction for radiation losses should be made in fixing the temperature of the mixture. On dealing with metals where the transfer of heat takes place quickly, the correction is usually ignored. In the case of a badly conducting solid such as rubber or glass, however, a considerable time elapses before the hot solid gives up its heat to the water. During this time there is an appreciable loss of heat by radiation

from the calorimeter, and the final temperature indicated is well below the value that should be used in calculating the result.

To obtain the corrected temperature, the following procedure is adapted:

From the observed temperature-time curve (graph A in fig. 1), the rate of cooling at the same point C, corresponding to a temperature (θ_1), is obtained by drawing a tangent to the curve at C. Since the rate of cooling at the room temperature (θ_R) is zero, a straight-line graph (fig.2) can be drawn showing rate of cooling in $^{\circ}\text{C}/\text{min}$ against θ $^{\circ}\text{C}$ from these two points. By Newton's law of cooling, the rate of cooling at any other temperature is proportional to the excess temperature of the body over the room temperature, and hence from his straight-line rate of cooling for any temperature can be read. From fig. 1, the mean temperature during the first minute interval is taken, and the rate of cooling in $^{\circ}\text{C}/\text{min}$ corresponding to this temperature is obtained from fig.2. this will give the amount by which the ordinate at the end of the minutes interval in graph A must be increased to obtain the corrected temperature. The correction for the next minute interval is obtained for the two intervals. Proceeding in this way the corrected curve B is obtained from which the corrected final temperature T is read.

Data collection and results: collect your data as shown below,

Time in min	θ in $^{\circ}\text{C}$	Cooling in $^{\circ}\text{C}/\text{min}$	Correction	Corrected temperature

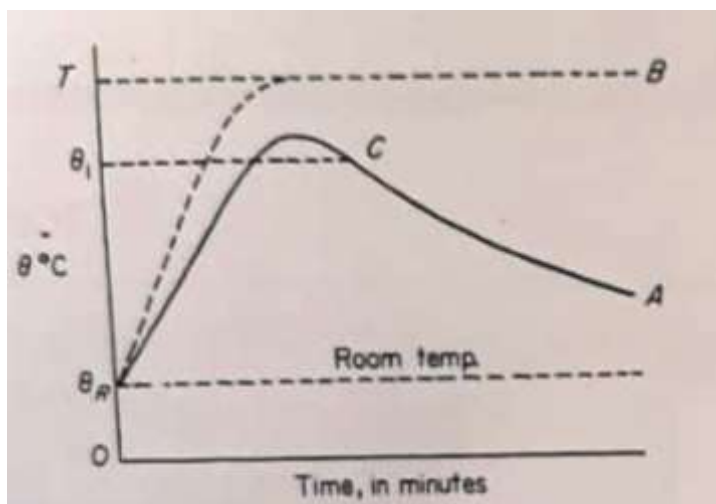


Figure 1

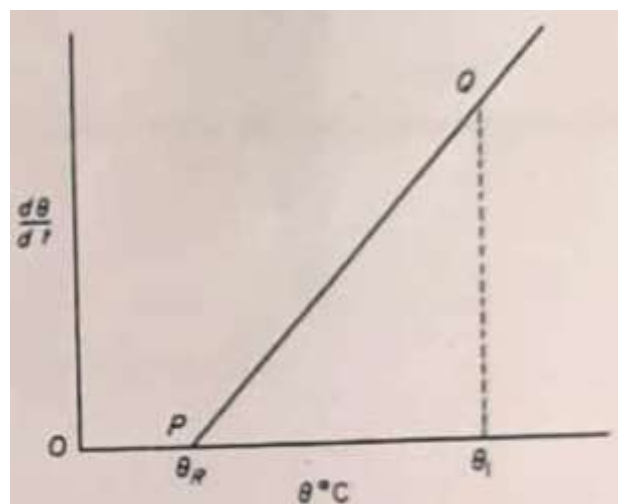


Figure 2

Experiment three

Determination of the coefficient of viscosity of water by capillary tube

Aim: To determine the viscosity coefficient of water using capillary tubes.

Apparatus: Any suitable constant head device such as that illustrated in fig.1, length of capillary tubing of diameter less than 2mm, beaker, stop-watch and thermometer.

Method: The apparatus is fitted up as shown in fig.1. by raising or lowering the runway tube, the head of water is adjusted so that the water emerges slowly as drops from the end of capillary. The water is collected in a weighed beaker and the rate of flow (Q) determined by weighing the amount of collected in a giving time (t). The pressure head (h) is measured. The experiment is repeated with different head of water and a graph is drawn between rate of flow and pressure head from (fig.2) which is found a mean value of Q/h (slope). The length (l) of the capillary is now measured and the mean radius of the tube is found by the mercury thread method. The temperature of the experiment is recorded. Collect your data in a table as below (table 1). Finally, use equation 1 to measure the viscosity of water.

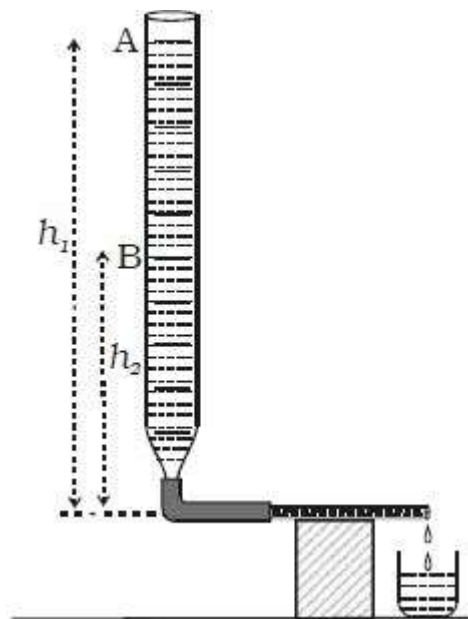


Fig. 1. Experiment setup

Table 1 Data collection

h	t ₁ (sec)	t ₂ (sec)	t _{av} (sec)	Flow rate $Q = \frac{V}{t_{av}}$

V: the volume of water collected by the lower tube (take 10 cm³ standard)

h: Length of mercury thread (height of water in the main beaker): take several values in meter
 a: Radius of capillary in meter
 l: Length of capillary tube in meter
 ρ : density of water=1000 kg/m³

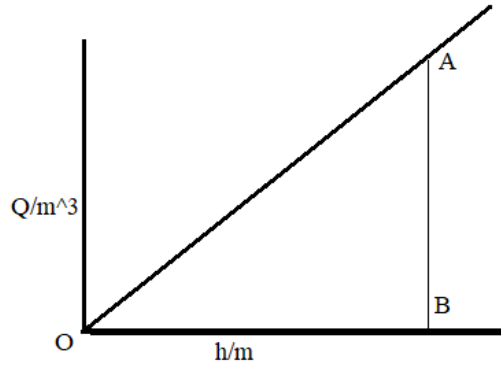


Fig.2

$$Q = \frac{P\pi a^4}{8l\eta}$$

$$P = g\rho h$$

$$\eta = \frac{g\rho h\pi a^4}{8lQ}$$

$$\eta = \frac{g\rho\pi a^4}{8l} \left(\frac{OB}{AB}\right) \quad \text{Where } \left(\frac{OB}{AB}\right) = \frac{h}{Q} \text{ from fig.2.}$$

or

$$\eta = \frac{g\rho\pi a^4}{8l} \frac{1}{\text{slope}} \quad \text{.....equ.1}$$

η is in unit of N m² s (pascal. Sec, Kg. m⁻¹ s⁻¹ or centipoise (cP)).

Experiment four

Coefficient of linear expansion of a solid by Fizeau's method

Objective To determine the coefficient of thermal expansion (α) for a metal (copper/ aluminum/ brass) rod using Fizeau's interferometer

Apparatus: Water bath filled with water, a Heater, Travelling Microscope, Specimen, thermometer, Scale.

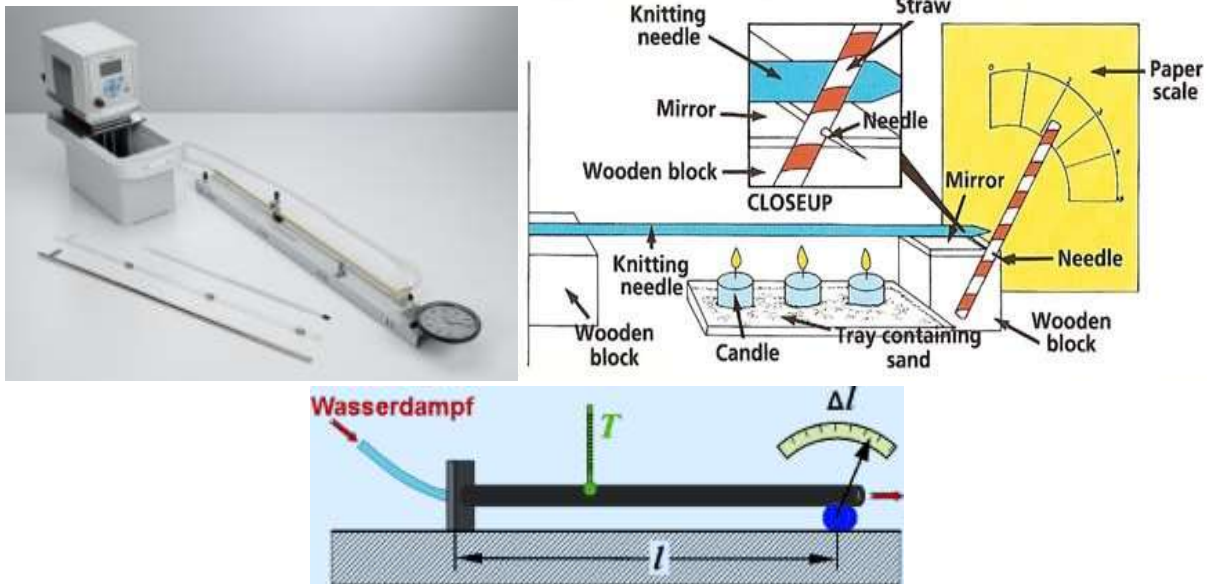


Fig. 1 Experimental setup

Procedure

1. Record the initial temperature θ_0 (room temperature) before beginning the experiment.
2. Measure length of the metal rod L_0 at room temperature.
3. Switch on the heater and let the water to hit.
4. The metal rod increases its temperature as the temperature of water rises.
5. Record the amount of change of rod's length ΔL as a function of temperature change $\Delta\theta$.
6. Record the data in table 1.
7. Plot between the change of temperature on X-axis and change of length of Y-axis.
8. Use equation 1 to calculate the linear expansion coefficient of the solid rod.

$$\eta = \frac{\Delta L}{(L_0)\Delta\theta}$$

$$\frac{\Delta L}{\Delta \theta} = \text{Slope}$$

Thus:

$$\eta = \frac{1}{(L_0)} * \text{slope} \dots\dots\dots 1$$

Table 1

$\Delta L = L - L_0$ (mm)	θ (degree)	$\Delta \theta = \theta - \theta_0$ (degree)

Theory:

Thermal expansion is a simple and universal property of material which is quite informative. It originates from the thermal vibrations of atoms of the material. Linear thermal expansion may be considered as the relative displacement of two points on a material due to absorption of thermal energy. The coefficient of linear expansion of a material is defined as equation 1.

Most materials expand somewhat when heated through a temperature range that does not produce melting or boiling. In a simple but useful atomic model of the material, the temperature rise causes an increase of the amplitude of vibration of the atoms in the material, which increases the average separation between the atoms, and the material expands as a result. It turns out that, provided the change in temperature isn't too big, the amount by which the material expands is directly proportional to the change in temperature. From the atomic model you can infer that the expansion should also be directly proportional to the size of the object. The constant of proportionality is called the coefficient of linear expansion and varies from material to material.

Not all materials expand to the same extent in different directions. Such materials are called anisotropic, i.e. not (an) the same (iso) in all directions (tropic). In an asymmetric crystal for example, linear expansion can have a different value depending on the axis along which the expansion is measured. It can also vary somewhat with temperature so that the degree of expansion depends not only on the magnitude of the temperature change, but on the absolute temperature as well.

Extra sources

Linear expansion of different materials: <https://physics.info/expansion/>

Experiment five

Determination of the atmospheric pressure by using a Boyle's law apparatus

Aim: To determine the pressure of atmosphere.

Apparatus: conventional Boyle's law apparatus such as that shown in fig.1.

Method: the experiment is commenced with the open tube T_2 well raised and closed tube T_1 containing the gas (air) as low as possible. Then, by gradually lowering T_2 and raising T_1 until the positions of the two tubes are interchanged, a series of readings for pressure and volume can be obtained extending over a wide range. At each step the position of A (top of T_1) and the mercury surface at B and C are read against the scale, a small-time interval being allowed between each set of reading to ensure that the gas in T_1 is at the temperature of its surroundings. The volume (V) of the gas may be taken as proportional to the length AB of the tube (assumed uniform), while the defences (h) between the readings at B and C gives the excess pressure of the gas above the atmospheric pressure (H). if the level of the mercury at C is below that at B, h will be negative.

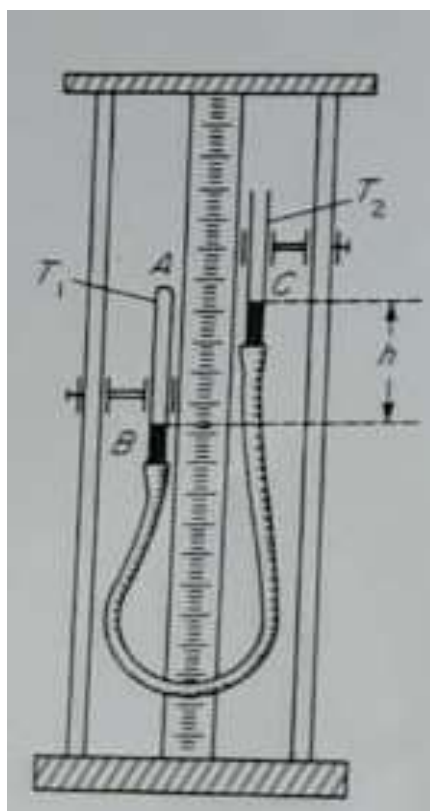


Fig. 1. Setup

Table 1 Data collection

Level A	Level B	Level C	$h = C-B$ (cm in mercury)	$V = A-B$ (scale unit)	$1/V$

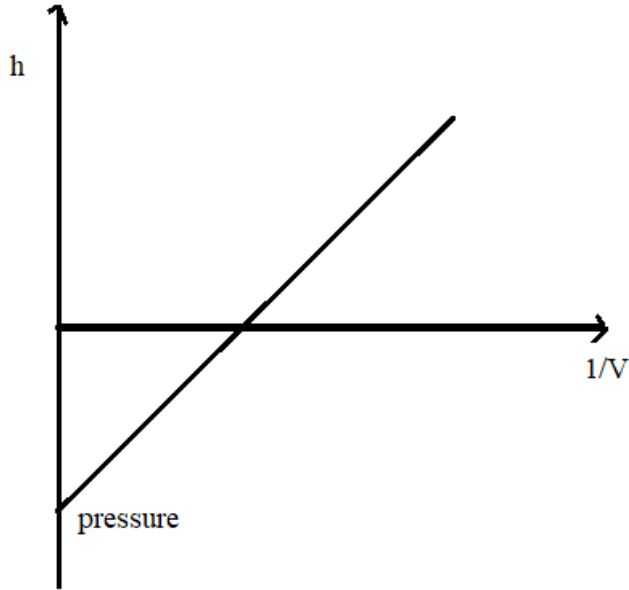


Fig.2

Theory: Boyle's law states that for a given mass of gas maintained at constant temperature, the volume (V) is inversely proportional to the pressure (P), or $PV = \text{constant}$. A plot of $1/V$ against P will thus yield a straight -line graph passing through the common zero. Now if H is the atmospheric pressure in cm mercury, and h is the difference on mercury levels in tubes T2 and T1, then, $P = H \pm h$. Thus, the plot of $1/V$ against h when extrapolated to cut the h -axis will locate the common zero and the intercept of OA (disregard the negative sign) is evidently the atmospheric pressure H .

Thus: $H = OA$ in cm mercury