Heat conduction (10 points)

Objective: determine the heat-conduction coefficient of a double-walled cup and estimate the water's equilibrium temperature.

Equipment

1. A large vessel.
2. A double-walled cup (one plastic cup inside another).
3. A jug for carrying water.
4. A stopwatch.
5. Two thermometers.
6. A stand for the thermometers and vessels.
7. Water (available in the reservoirs).
8. An electric immersion heater. **PRECAUTIONS**: connect or disconnect it only when it is fully immersed in water. Do not touch **the heater or water** while the heater is connected. The thermometer and heater must not touch.

Introduction

Fourier's law states that the heat ΔQ passing through a wall in a time interval Δt is proportional to the temperature difference ΔT between its two sides:

$$\frac{\Delta Q}{\Delta t} = B\,\Delta T \qquad (1),$$

where the wall's heat-conduction coefficient *B* depends on its thickness, shape, material, and so on.

Procedure

1. Assemble the apparatus shown. Piece *s* fits into notch *m* to hold the cup (its use is optional).

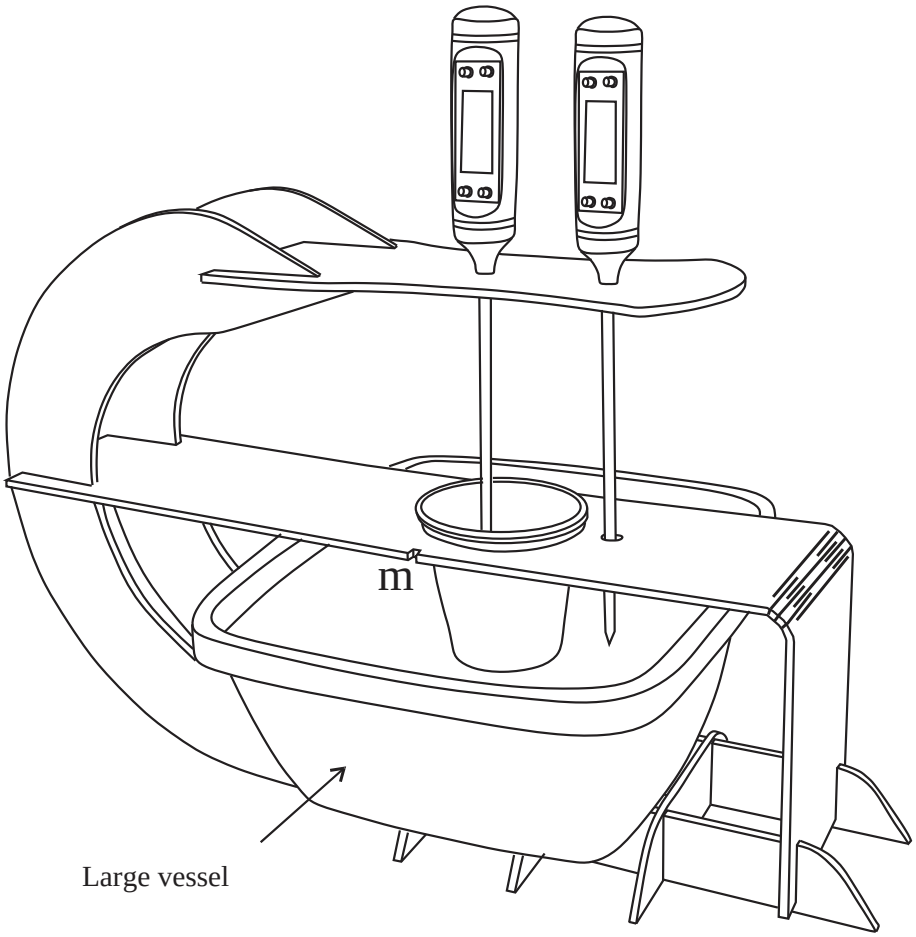
2. Fill the large vessel with hot water and the double-walled cup with cold water. Both water levels must reach the mark on the cup. Initially, the hot water should be slightly above 60 °C, and the cup's water as cold as possible. The cup's mark corresponds to 150 ± 2 ml of water.

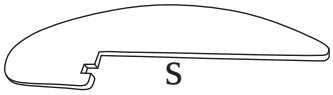
3. Simultaneously measure the cold-water temperature T_f and hot-water temperature T_c as functions of time t. Take these measurements while the hot-water temperature is approximately between 60 °C and 50 °C. *Do not stir the liquids.*

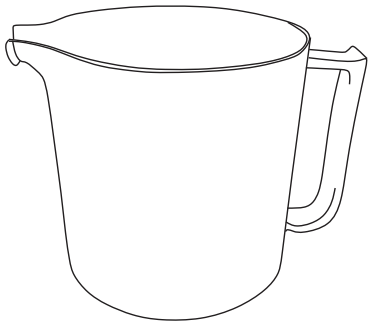
Experimental Test

(Official Spanish version)

E1 - 2







Jug

Tasks

1. Heat-transfer coefficient of the double-walled cup

1.1 [3 points] Record the values of t, T_c, T_f and any other relevant quantities in Table 1.

1.2 [2 points] Plot T_c and T_f against t (Graph 1).

1.3 [3 points] Construct a second graph (Graph 2) from which the coefficient B and its uncertainty can be determined. A constant term associated with heat transfer to the surroundings must be added to the model in equation (1). You need not calculate this constant.

2. Equilibrium temperature

2.1 [1 point] On one set of axes, plot $\Delta T = T_c - T_f$ against T_c and against T_f (Graph 3).

2.2 [1 point] Use Graph 3 to estimate the temperature at which the water in the two vessels would reach thermal equilibrium. No uncertainty calculation is required here.

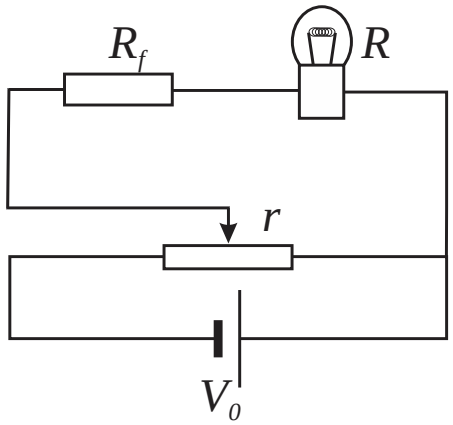
Molar mass	μ	0.018 Kg · mol^{-1}
Vapour pressure	P_v	3.17 × 10^3 Pa
Density	ρ	1000 kg · m^{-3}
Acidity	pK_a	13.99
Specific heat capacity	c	4.18 × 10^3 J · kg^{-1} · K^{-1}
Thermal conductivity	λ	0.61 W · m^{-1} · K^{-1}
Refractive index	n	1.33
Viscosity	η	8.9 × 10^{-4} kg · m^{-1} · s^{-1}

Heat radiation

Objective: determine the length and diameter of an incandescent lamp's filament.

Equipment

1. A DC power supply (*always set to* $V_0 = 6$ V)).
2. A breadboard with a variable resistor, a lamp and a fixed resistor $R_f = 1\ \Omega$, connected as shown.
3. A multimeter (*use it only as a voltmeter; using it to measure resistance and/or current is forbidden*).
4. A screwdriver (*to adjust the variable resistance*).
5. Three pairs of connecting leads.



Introduction

The filament is a thin helical tungsten wire. Current heats it to incandescence, so it emits light and heat. Its ohmic resistance R increases linearly with absolute temperature T:

$$\frac{\Delta R}{\Delta T} = \alpha R_0 \qquad (1),$$

where R_0 is the filament's resistance at room temperature and $\alpha = 5{,}1\times10^{-3}\ K^{-1}$ is tungsten's temperature coefficient of resistivity. Tungsten's resistivity at 20 °C is $\rho_0 = 5{,}5\times10^{-8}\ \Omega\cdot\mathrm{m}$.

Procedure and tasks

1. Filament characteristics

Adjust resistance r by turning the protruding screw. Because of the nature of this variable resistor, its sensitivity to screw rotation varies considerably over the measurement range; this does not indicate a fault.

1.1 Connect the leads from the breadboard to the power supply to make the circuit shown.

1.2 [2,5 points] Vary r and measure the voltage V across the lamp: take at least ten readings between 0,030 V and 0,100 V, and at least ten more between 0,100 V and 5,60 V. Simultaneously measure the other circuit voltage(s) needed to find the lamp current I, its ohmic resistance R and the power P dissipated in it. Enter the data in Table 1.

1.3 [0,5 points] Plot the lamp's current–voltage characteristic, I against V (Graph 1).

1.4 [0,5 point] Plot P against R (Graph 2).

2. Lamp resistance near room temperature

Near room temperature, the temperature dependence of the filament's ohmic resistance can be neglected.

2.1 [1 point] Use Graph 1 to determine the resistance R_0 near room temperature, with its uncertainty.

3. Relation between power dissipation and resistance at high temperatures

At high temperatures, the filament loses energy mainly by radiation. The power dissipated is then:

$$P = A\sigma T^4 \qquad (2),$$

where A is the filament's surface area and $\sigma = 5{,}67\times10^{-8}$ $Wm^{-2}K^{-4}$ is the Stefan–Boltzmann constant.

3.1 [1,5 points] From equations (1) and (2), find a relation between the dissipated power P and the filament resistance R.

3.2 [2 points] Linearize the relation found in 3.1 and plot it (Graph 3).

4. Filament length and diameter

4.1 [1 point] Determine the filament length, with its uncertainty.

4.2 [1 point] Determine the filament diameter, with its uncertainty.