**Série de exercícios práticos Temperatura**
**Disciplina ACA221 Instrumentos Meteorológicos/IAG/USP**
**Prof. Humberto Rocha**

1. Sobre escalas de temperatura:

a) O que entende-se por ponto de fusão e ponto de ebulição ?
b) Na escala Celsius, o que significam os valores 0 e 100 ?
c) Na escala Fahrenheit, o que significam os valores 0 e 96 ?
d) O aumento de 1°C equivalente aproximadamente a quantos °F ?
e) Calcule a conversão dos valores na tabela seguinte, de Celsius para Fahrenheit e para Kelvin.
f) Uma informação da mídia comunicou que, com a passagem de uma frente fria, a temperatura do ar caiu 10°C em certa localidade *A*, e outra noticia que caiu 18 °F em outra localidade próxima *B*. Supondo as informações certas, em qual delas a queda de temperatura foi maior ?
g) Um meteorologista criou sua própria escala linear de temperaturas, onde os valores de O (zero) e 10 (dez) correspondem, respectivamente, a 37°C e 40°C. Qual a temperatura de mesmo valor numérico nestas duas escalas ?

| °C | °F | K |
|---|---|---|
| 0 | | |
| 100 | | |
| 20 | | |

**2.** Sobre os termômetros de líquido em vidro:

a) Quais são seus componentes básicos ?

b) Quais os principais líquidos utilizados ? Descreva o ponto de fusão e o ponto de ebulição dos líquidos, e discuta o intervalo de medição em que se mostram convenientes como elemento sensor.

b) Qual a diferença de termômetros de bulbo com imersão parcial e total ?
c) Ao se utilizar um termômetro, quais características devem ser notadas, e quais cuidados tomados para a melhor leitura ?

**3.** Sobre termômetros eletrônicos

Um termômetro do tipo termistor, ou um do tipo RTD, pode trabalhar como um equipamento em que se aplica uma corrente de excitação constante ($I_{EX}$), e mede-se a ddp ($V_0$) resultante para se estimar a temperatura, conforme figura anexa. Há também outra configuração em que se aplica uma ddp constante ($V_{EX}$) e mede-se a corrente. Em ambos estima-se a resistência como produto resultante. O termistor e o RTD:
a) são feitos de materiais diferentes, quais são comumente ?
b) tem uma característica comum, mas com respostas diferentes: qual é ? (conforme figura )
c) tem diferentes sensibilidades à temperatura, qual a maior ? (conforme figura anexa)
d) pela diferente sensibilidade, isoladamente, contribui para que qual deles tenha mais acurácia, por ex. em um intervalo de medição de 20 a 30° C ?

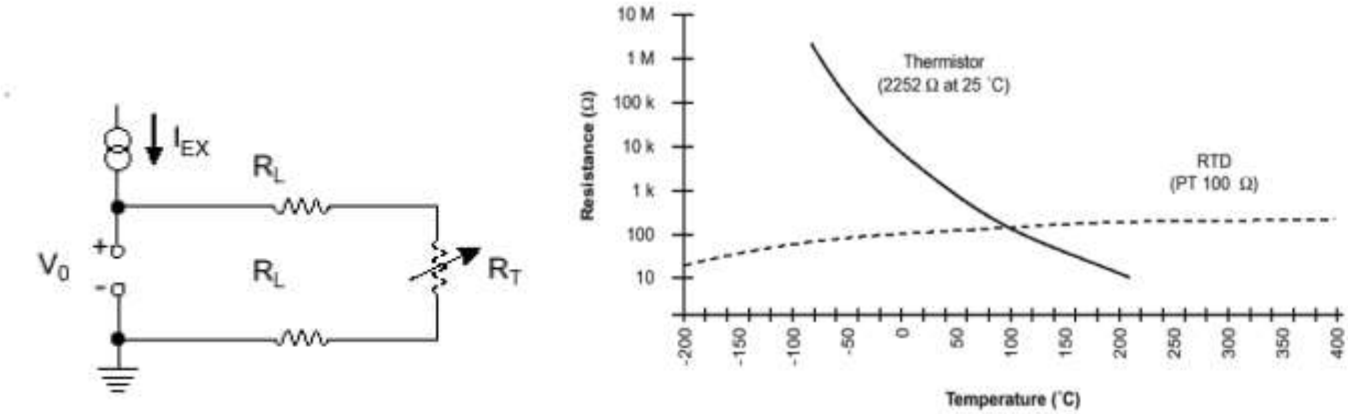


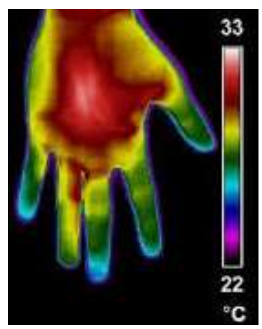

Fig. 1: (esq) circuito elétrico com termômetro $R_T$, com duas resistências em série $R_L$ para evitar aquecimento do termômetro; (dir) relação entre resistência e temperatura para um termistor e um RTD.

**4.** Qual o princípio de funcionamento do termopar, e quais vantagens/desvantagens há sobre o RTD e o termistor ?

**5.** Sobre o termômetro infravermelho:

a) qual a sua principal finalidade ?

b) certa medida de temperatura (Fig. anexa) foi estimada com emissividade de 0,90, mas que deveria ter sido prescrita 0,98 (portanto um aumento de aproximadamente 8,1%). Estime a diferença percentual de temperatura em K decorrente desta correção de emissividade.




6. Comente como a informação da temperatura é importante nas seguintes situações do cotidiano (pesquise individualmente se achar necessário para descrever corretamente):

a) Saúde humana
b) Saúde animal e produção de bens
c) Consumo de energia
d) Agricultura
e) Operação de rodovias e aeroportos
f) Funcionamento de um veículo
g) Comércio de vestuários
h) Comércio de alimentos

## ꞮATURE SCALES

There are many types of thermometer, but each makes use of a particular thermometric property (i.e. a property whose value changes with temperature) of a particular thermometric substance. For example: a mercury-in-glass thermometer makes use of the change in length of a column of mercury confined in a capillary tube of uniform bore; a platinum resistance thermometer makes use of the increase in the electrical resistance of platinum with increasing temperature.

In order to establish a temperature scale it is necessary to make use of **fixed points**: A fixed point is the single temperature at which it can confidently be expected that a particular physical event (e.g. the melting of ice under specific conditions) always takes place. Three such points are defined below.

**The ice point** is the temperature at which pure ice can exist in equilibrium with water at **standard atmospheric pressure** (i.e. at a pressure of 760 mm of mercury).

**The steam point** is the temperature at which pure water can exist in equilibrium with its vapour at standard atmospheric pressure.

**The triple point** of water is that unique temperature at which pure ice, pure water and pure water vapour can exist together in equilibrium.

The triple point is particularly useful, since there is only one pressure at which all three phases (solid, liquid and gas) can be in equilibrium with each other.

The SI unit of temperature is the kelvin (K). **An interval of one kelvin is defined as being 1/273.16 of the temperature of the triple point of water as measured on the thermodynamic scale of temperature** (see later in this

### INSTRUMENT ACCURACY

| | | |
|---|---|---|
| **RANGE** | -30 TO 100 °C | ±0.20 °C from −30 to 100 °C |
| | -22 TO 212 °F | ±0.36 °F from −22 to 212 °F |

work the cable resistance can be taken into account. Accuracies of the types of thermistor beads used here is, **+/- 0.5°C**, (Model 3800-1-1-1), or **+/- 0. 2°C** ( Model 3800-1-2-1). Standard temperature ranges are -50 to 150 degrees C . High temperature versions are -30 to 230 degrees C.

## Operating Range

Measuring Range −40°C to +80°C

## Accuracy

0°C to 70° ± 0.2°C

(accuracy may be reduced outside of range)

section and in section 16.6). The triple point of water is the fixed point of the scale and is assigned the value of 273.16 K. On this basis absolute zero is 0 K, the ice point is 273.15 K, and the steam point is 373.15 K.

Another unit, the **degree Celsius** (°C), is often used and is defined by

$$\theta = T - 273.15 \qquad [13.1]$$

where

$\theta$ = temperature in °C, and

$T$ = temperature in K.

The Celsius scale was originally defined by using the ice and steam points as fixed points of the scale, and designating them as 0 °C and 100 °C respectively. Bearing in mind that these temperatures are respectively 273.15 K and 373.15 K, we can easily see that the more recent definition (equation [13.1]) is consistent with this. It also follows from equation [13.1] that **a temperature change of 1 K is exactly equal to a temperature change of 1 °C.**

A mercury-in-glass thermometer could be calibrated by marking the positions of the mercury when the thermometer is at the ice point and the steam point, and then dividing the interval between these two marks (designated 0 °C and 100 °C respectively) into a hundred equal divisions. If this procedure were to be adopted, the Celsius temperature $\theta$ corresponding to a length $l_\theta$ of the mercury column would be given by

$$\theta = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100 \qquad [13.2]$$

where $l_0$ and $l_{100}$ are the lengths of the mercury column at 0 °C and 100 °C respectively. Such a calibration regards equal increases in the length of the mercury column as being due to equal increases in temperature. There is of course no valid reason for making this assumption, and so if such a thermometer is used, it is important to stress that the measured temperatures are according to the mercury-in-glass scale of temperature. If a platinum resistance thermometer were to be calibrated by making an equivalent assumption, i.e. that equal increases in temperature produce equal increases in the resistance of platinum, then temperatures measured by this thermometer would be according to the platinum resistance scale. These two scales coincide only at the fixed points (0 °C and 100 °C), because, as might be expected, the volume of mercury and the resistance of platinum do not vary in the same way.

## 13.3 LIQUID-IN-GLASS THERMOMETERS

These are simple to use and cheap to buy, but cannot be used for accurate work because:

(i) parallax errors prevent the scale being read to better than about 0.1 °C;

(ii) non-uniform bore limits the accuracy to about 0.1 °C;

(iii) the glass expands and contracts and can take many hours to reach its correct size, and therefore spoils the calibration;

(iv) the accuracy of the calibration depends on whether or not the thermometer is upright, and on how much of the stem is exposed.

This type of thermometer is easily adjusted to the constant-volume gas thermometer scale by suitably spacing the degree markings on the glass. Liquid-in-glass thermometers have relatively large heat (thermal) capacities, and this limits their use in two distinct ways:

(i) they cannot be used to follow rapidly changing temperatures; and

(ii) they can considerably affect the temperature of the body whose temperature they are being used to measure.

The majority of liquid-in-glass thermometers use mercury as the thermometer liquid. This is because:

(i) mercury is opaque and therefore easily seen;

(ii) mercury is a good conductor of heat and therefore can rapidly take up the temperature of its surroundings;

(iii) mercury does not wet (i.e. stick to) the glass.

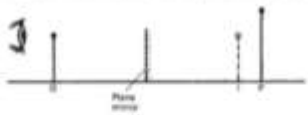
The range of such a thermometer is from −39 °C (the freezing point of mercury) to something below its normal boiling point of 357 °C. This upper limit can, however, be extended by filling the thermometer with an inert gas such as nitrogen; this increases the pressure on the mercury so that its boiling point can be increased to about 800 °C. Ordinary soda-lime glass or Pyrex would soften at such a temperature, and therefore the thermometer would probably be made from fused quartz. If the mercury is replaced by ethyl alcohol, temperatures as low as −114.9 °C (the freezing point of alcohol) can be measured. Alcohol is also more sensitive to temperature change than mercury but its expansion is very non-linear. The use of liquid pentane can reduce the lower limit even more, to about −200 °C.

## 20.3 IMAGE LOCATION BY NO PARALLAX

The method of no parallax can be used to locate the positions of both real and virtual images. The illuminated object and screen method (see, for example, section 19.7) can be used for real images only. In order to illustrate the no-parallax technique, we shall describe how it is used to locate the position of a real object produced by a plane mirror.

An object pin, O, is stood in front of a vertical plane mirror (Fig. 20.6).

**Fig. 20.6**
Image location by no parallax




A second pin, P, is now placed behind the mirror. This pin should be large enough for the observer to see part of it over the top of the mirror. The observer looks at both P and the image, I, of O and then moves P until it appears to coincide with I. If P and I are merely in the observer's line of sight, rather than actually in the same place, they appear to move relative to each other when the observer moves his or her head from side to side (see Fig. 20.7(a)). There is said to be **parallax** between P and I.

**Fig. 20.7**
(a) Parallax between P and I. (b) No parallax between P and I

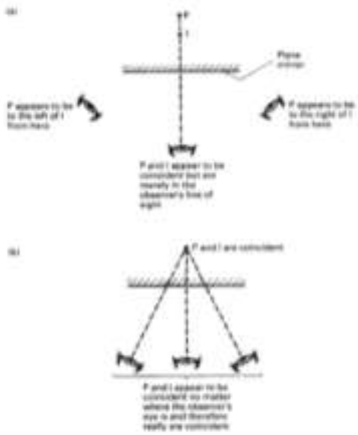



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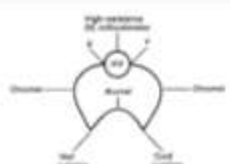
**Fig. 13.3**
Thermocouple with reference junction




the cold junction is therefore always the same, and so it is a simple matter to adjust the meter reading to allow for this EMF. (**Note.** The use of the terms 'hot junction' and 'cold junction' arises because thermocouples are normally used to measure temperatures above 0 °C, in which case the reference junction is the colder of the two.)

Thermocouples have very small heat capacities, and so have very little effect on the temperature of the body whose temperature they are measuring, and can measure rapidly fluctuating temperatures. In both these respects thermocouples are superior to other types of thermometer. In addition, they are cheap and easy to use, and are ideal for use with a pen-recorder.

The thermoelectric EMFs of many pairs of metals have been measured as a function of the hot junction temperature $\theta$ as measured by a constant-volume gas thermometer and expressed in degrees Celsius. In every case if the cold junction is maintained at 0 °C, it is found that to a good approximation the EMF $E$ is given by

$$E = \alpha\theta + \beta\theta^2 \qquad [13.4]$$

where the values of $\alpha$ and $\beta$ depend on the particular pair of metals concerned. This relationship is, of course, parabolic and therefore there exists a value of $\theta$, known as the **neutral temperature**, $\theta_n$, for which $dE/d\theta = 0$ (Fig. 13.4). It is clearly not desirable to use a thermocouple to measure temperatures close to its neutral temperature, because the variation of EMF with temperature is small and the thermometer is therefore insensitive in this region.

The particular pair of metals used depends on the temperature range for which the thermocouple is intended. Chromel/alumel thermocouples are normally used up to about 1100 °C, and produce a thermoelectric EMF of about 4 mV for every 100 °C difference in temperature between the hot and cold junctions. Above 1100 °C and up to about 1700 °C platinum/platinum–rhodium is used on account of the high melting points of platinum and platinum–rhodium. All these metals, particularly platinum and platinum–rhodium alloy, are readily available in states of high purity and so can be used to make thermocouples which give highly

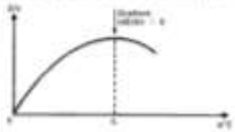



**Fig. 13.4**
Thermocouple EMF as a function of temperature





reproducible results. The disadvantage of platinum/platinum–rhodium is its relatively low thermoelectric EMF, about 1 mV per 100 °C.

For the most accurate work the millivoltmeter is replaced by a potentiometer (see Chapter 38). The use of a potentiometer, however, prevents the thermocouple being used to measure rapidly changing temperatures.

The values of $\alpha$ and $\beta$ of equation [13.4] which are relevant to the commonly used thermocouple materials can be obtained from tables, and can be used in equation [13.4] to determine $\theta$ once $E$ has been measured. Alternatively, calibration charts (plots of $E$ against $\theta$) are available.

## 13.5 RESISTANCE THERMOMETERS

Resistance thermometers rely on the fact that the resistances of metals are temperature-dependent, and therefore a measurement of resistance can be used as a measurement of temperature. They are usually made of platinum because of its high temperature coefficient of resistance and high melting point (1773 °C), features which make platinum resistance thermometers both sensitive and useful over large ranges of temperature. Also, platinum is readily available in a state of high purity, so that the measurements made with one particular platinum resistance thermometer are likely to match those made with another. The platinum is in the form of wire coiled on a suitable insulator such as mica or





platinum is in the form of wire coiled on a suitable insulator such as mica or
alumina. In use, the thermometer forms one arm of a Wheatstone bridge (see Chapter 37). This arrangement allows very slight changes in resistance, and therefore in temperature, to be measured. Platinum resistance thermometers are extremely accurate from −200 °C up to 1200 °C. The main disadvantage of thermometers of this type is that they have relatively large heat capacities. This means that they take a considerable time to come into thermal equilibrium with their surroundings, and therefore prevents them following rapidly changing temperatures. This is precluded anyway because a Wheatstone bridge has to be used.

When calibrated against constant-volume gas thermometers the resistance $R$ of platinum is found to vary with Celsius temperature $\theta$ according to

$$R = R_0(1 + \alpha\theta + \beta\theta^2) \qquad [13.5]$$

where $R_0$ is the resistance of the platinum at 0 °C and $\alpha$ and $\beta$ are constants. The values of $R_0$, $\alpha$ and $\beta$ pertaining to any particular thermometer are found by measuring its resistance at the ice point, the steam point and at the melting point of sulphur (444.6 °C), and inserting the three pairs of values of $R$ and $\theta$ in equation [13.5]. Once $R_0$, $\alpha$ and $\beta$ have been found equation [13.5] can be used to determine $\theta$ for any measured value of $R$.

## 13.6 THERMISTORS

These devices, like resistance thermometers, rely on their change of electrical resistance with temperature as a means of measuring temperature. Unlike resistance thermometers, however, they have negative temperature coefficients of resistance; their resistance decreasing approximately exponentially with increasing temperature. Thermistors are semiconducting devices cheaply manufactured out of several different mixtures of semiconducting oxide powders





($Fe_3O_4 + MgCr_2O_4$ is a common mixture). They are very robust. When a Wheatstone bridge circuit is used to measure their resistance they are about twenty times as sensitive as resistance thermometers. The resistance of the connecting





wires is of no significance, since the devices themselves typically have a resistance of 1 kΩ. Thermistors have very small thermal capacities, and therefore respond quickly and have little effect on the temperature they are measuring. The range is typically −70 °C to 300 °C. They are less stable than resistance thermometers, and therefore less accurate.

## 13.7 THE CONSTANT-VOLUME GAS THERMOMETER

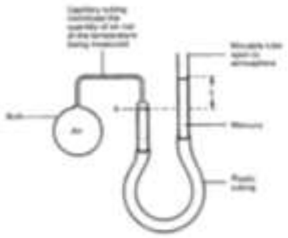
A simple constant-volume gas thermometer is shown in Fig. 13.5. When the thermometer is in use the bulb is placed inside the enclosure whose temperature is required. The gas in the bulb (air in the simplest versions) expands and forces mercury up the movable tube. The height of this tube is then adjusted to bring the mercury in the left-hand tube back to its original position at a fixed mark A. The gas now has its original volume. At this stage the head of mercury $h$ is measured and the pressure $p_\theta$ of the gas is calculated from $p_\theta = p_A + h$ where $p_A$ is the prevailing atmospheric pressure expressed in mm of mercury.

If $p_0$ and $p_{100}$ are the pressures at 0 °C and 100 °C respectively, the temperature of the enclosure can be found from

$$\theta = \frac{p_\theta - p_0}{p_{100} - p_0} \times 100$$

where $\theta$ is the desired temperature in °C according to the constant-volume gas scale.

Fig. 13.4
Constant-volume gas thermometer



There are a number of sources of error:

(i) the bulb expands;

(ii) air is not an ideal gas;

(iii) the air in the capillary tube is not at the temperature being measured.



## EXAMPLE 13.1

A particular resistance thermometer has a resistance of 30.00 Ω at the ice point, 41.58 Ω at the steam point and 34.59 Ω when immersed in a boiling liquid. A constant-volume gas thermometer gives readings of $1.333 \times 10^5$ Pa, $1.821 \times 10^5$ Pa and $1.528 \times 10^5$ Pa at the same three temperatures. Calculate the temperature at which the liquid is boiling: (a) on the scale of the gas thermometer, (b) on the scale of the resistance thermometer.

### Solution

The Celsius temperature $\theta_g$, according to the gas thermometer scale, is given by

$$\theta_g = \frac{p_\theta - p_0}{p_{100} - p_0} \times 100$$

where $p_\theta$ is the gas pressure at the temperature of the boiling liquid and $p_0$ and $p_{100}$ are the gas pressures at 0 °C and 100 °C respectively. Thus

$$\theta_g = \frac{1.528 \times 10^5 - 1.333 \times 10^5}{1.821 \times 10^5 - 1.333 \times 10^5} \times 100$$

$$= \frac{0.195}{0.488} \times 100$$

$$= 39.96\ °C$$

The Celsius temperature $\theta_r$ according to the resistance scale is given by

$$\theta_r = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100$$

where $R_\theta$ is the resistance at the temperature of the boiling liquid and $R_0$ and $R_{100}$ are the resistance values at 0 °C and 100 °C respectively. Thus

$$\theta_r = \frac{34.59 - 30.00}{41.58 - 30.00} \times 100$$

$$= \frac{4.59}{11.58} \times 100$$

$$= 39.64\ °C$$

## THERMOMETRY (Chapter 13)

**C1** A bath of oil is maintained at a steady temperature of about 180 °C, which is measured both with a platinum resistance thermometer and a mercury-in-glass thermometer. Explain why you would expect the temperatures indicated by the two thermometers to be different. At what temperatures would the two thermometers show the same value? [J]

**C2** Explain why two thermometers, using different thermometric properties and calibrated at two fixed points, would not necessarily show the same termperature except at the fixed points.

Why is the constant volume gas thermometer chosen as a standard?

What type of thermometer is recommended to measure accurately a temperature of **(a)** about 15 K, and **(b)** 2000 K? (No details required.) [W]

**C3** **(a)** Explain how a temperature scale is defined.

**(b)** Discuss the relative merits of **(i)** a mercury-in-glass thermometer, **(ii)** a platinum resistance thermometer, **(iii)** a thermocouple, for measuring the temperature of an oven which is maintained at about 300 °C. [J]

**C5** Describe the structure of a simple constant volume gas thermometer. Discuss how it would be used to establish a scale of temperature.

Explain why the same temperature measured on two different scales need not have the same value.

Discuss the circumstances in which: **(a)** a gas thermometer, and **(b)** a thermocouple might be used.

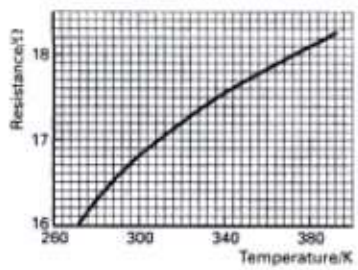
Why is it generally not sensible to use a thermoelectric EMF as the physical property used to *define* a scale of temperature? [L]

Explain why the same temperature measured on two different scales need not have the same value.

Discuss the circumstances in which: **(a)** a gas thermometer, and **(b)** a thermocouple might be used.

Why is it generally not sensible to use a thermoelectric EMF as the physical property used to *define* a scale of temperature? [L]

**C6** The graph below shows the variation in resistance of a piece of platinum wire with the temperature being measured on the ideal gas scale.




What is the *Celsius* temperature corresponding to a resistance of 17 Ω on

**(a)** the ideal gas scale, and

**(b)** the platinum resistance scale? [L]

**C4** The resistance of the element in a platinum resistance thermometer is 6.750 Ω at the triple point of water and 7.166 Ω at room temperature. What is the temperature of the room on the scale of the resistance thermometer? The triple point of water is 273.16 K. State one assumption you have made. [L]

**C5** Describe the structure of a simple constant volume gas thermometer. Discuss how it would be used to establish a scale of temperature.

**C7**

| | *Resistance of resistance thermometer* | *Pressure recorded by constant volume gas thermometer* |
|---|---|---|
| *Steam point* 100 °C | 75.000 Ω | $1.10 \times 10^7\ \mathrm{N\,m^{-2}}$ |
| *Ice point* 0 °C | 63.000 Ω | $8.00 \times 10^6\ \mathrm{N\,m^{-2}}$ |
| *Room temperature* | 64.992 Ω | $8.51 \times 10^6\ \mathrm{N\,m^{-2}}$ |

Using the above data, which refer to the observations of a particular room temperature using two types of thermometer, calculate





the room temperature on the scale of the resistance thermometer and on the scale of the constant volume gas thermometer.

Why do these values differ slightly? [L]

**C8** The value of the property $X$ of a certain substance is given by

$$X_t = X_0 + 0.50t + (2.0 \times 10^{-4})t^2,$$

where $t$ is the temperature in degrees Celsius measured on a gas thermometer scale. What would be the Celsius temperature defined by the property $X$ which corresponds to a temperature of 50 °C on this gas thermometer scale? [L]

**(i)** Describe, in principle, how you would conduct an experiment to obtain line B.

**(ii)** If $\theta = 40$ °C recorded by an $X$-scale thermometer, what temperature would be recorded by a $Q$-scale thermometer?

**(iii)** At what two temperatures will the $X$ and $Q$ scales coincide?

**(c)** The ideal gas scale of temperature is one based on the properties of an ideal gas. What is the particular virtue of this scale? Describe very briefly how readings on such a scale can be obtained using a thermometer containing a real gas. [L]

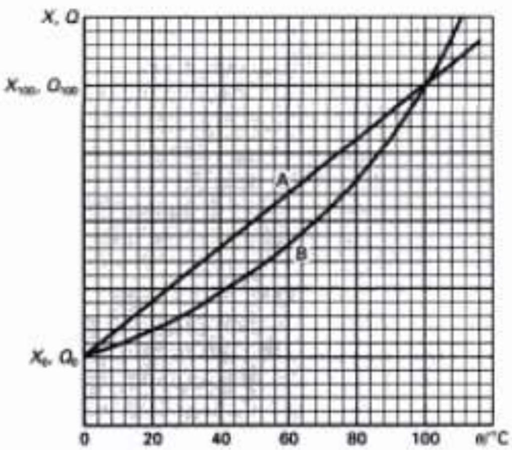
**C9 (a)** What is meant by a thermometric property? What qualities make a particular property suitable for use in a practical thermometer?

A Celsius temperature scale may be defined in terms of a thermometric property $X$ by the following equation:

$$\theta = \frac{X - X_0}{X_{100} - X_0} \times 100\,^{\circ}\mathrm{C} \qquad (1)$$

where $X_0$ is the value of the property at the ice point, $X_{100}$ at the steam point, and $X$ at some intermediate temperature. If $X$ is plotted against $\theta$ a straight line always results no matter what thermometric property is chosen. Explain this.

**(b)** On the graph, line A shows how $X$ varies with $\theta$ (following equation (1) above), line B shows how a second thermometric property $Q$ varies with $\theta$, the temperature measured on the $X$ scale.




**C10** A temperature $T$ can be defined by $T = T_f(X/X_f)$, where $T_f$ is the assigned temperature of a fixed point and $X$ and $X_f$ are the values of a thermometric property of a substance at $T$ and $T_f$ respectively. On the ideal-gas scale, the fixed point is the triple point of water and $T_f = 273.16$ K.

**(a)** List *four* thermometric properties which are used in thermometry. Explain why certain thermometric properties of a gas are taken as standard.

**(b)** Explain what is meant by a fixed point and by the triple point of water.

**(c)** Sketch and label the simple form of constant-volume gas thermometer found in school laboratories, and describe how it is used to determine the boiling point of a liquid on the ideal-gas scale.

**(d)** For a thermometer which is not based on the properties of gases, explain how you would calibrate it in terms of the ideal-gas scale.

**(e)** Compare the advantages and disadvantages of the constant-volume gas thermometer with those of any *two* other types of thermometers.

**(f)** The pressures recorded in a certain constant-volume gas thermometer at the triple point of water and at the boiling point of a liquid were 600 mm of Hg and 800 mm of Hg respectively. What is the apparent temperature of the boiling point? However, it was found that the volume of the thermometer increased by 1% between the two temperatures. Obtain a more accurate value of the boiling point. [W]



**5. Qual a diferença de termômetros de bulbo com imersão parcial e total ?**

R: imersão total só a porção com líquido é exposta ao meio com temperatura a medir; por ex se for um meio com água a 50°C, deve-se imergir até a escala aproximada de 50º C e então removido rapidamente para fazer a leitura.

Imersão Parcial ocorre quando o bulbo e uma pequena extensão além do bulbo ficam em contato com o meio. Por esta incerteza, são relativamente menos acurados que os de imersão total.

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**6. Quais os liquidos utilizados nos termômetros de bulbo e qual sua acurácia relativa ?**

R: Mercury o mais confiável, provê maior repetibilidade, opera no intervalo -40 a 500°C e tem um coeficiente de expansão linear.

Outros liquids orgânicos são álcool, querosene, tolueno, que são coloridos artificialmente. Estes líquidos podem colar nas paredes internas do vidro em pequenas gotículas, e não tem coeficientes de expansão lineares, o que reduz sua acurácia.

## How do I re-join a separated liquid column?

How you re-join a separation depends on where the separation occurs.

SEPARATION AT THE UPPER PORTION OF THE MERCURY COLUMN:

Most well constructed thermometers contain an expansion chamber at the extreme top of the capillary. This chamber allows for the overflow of mercury should the thermometer be overheated. If the instrument does not have scale divisions over 250°C it serves as a means of rejoining this type of separation. While holding the instrument in a vertical position, slowly heat the bulb until the separated segments and a portion of the main column enter the chamber. Never heat the bulb directly over an open flame and be sure the heating medium has a flash point above the highest temperature graduated on the thermometer. Do not allow the chamber to be more than half to three quarters full, otherwise the bulb may break due to excessive pressure. The nitrogen pressure will force a rejoining of the mercury. If necessary tap the thermometer gently. After the mercury is re-joined, continue to hold the thermometer vertically, and examine the column as it cools and retracts to be sure it is intact.

SEPARATION IN THE CONTRACTION CHAMBER:

Many thermometers contain scale ranges which begin well above ambient temperature. The thermometers have a contraction chamber or enlargement which prevents the mercury from entering the bulb at ambient temperatures. Heavy jarring of the instrument or thermal shock can cause a separation in this chamber. If the separated mercury is in the form of a speck or small amount, invert the thermometer and gently tap it against the palm of the other hand. This will cause a larger separation, adding additional volume and weight to the separated portion. The thermometer should then be righted and only the tip of the bulb should be dipped in ice water or salted ice water. Remove from the water and gently tap the bulb on a desk blotter and allow the separated portion to fall to the bottom of the chamber and re-join the mercury reservoir. Allow thermometer to warm to room temperature and check to be sure all separations have been recovered.

SEPARATION IN THE LOWER PORTION OF THE COLUMN:

The general procedure for joining this more difficult (and less frequent) type of separation is to cool the bulb only to a temperature sufficient to retract all the mercury into the bulb. A slow and careful return to ambient temperature will return an intact column. Caution must be taken when the range is such that at the freezing point of mercury (-38.8°C) some mercury still remains in the capillary. If the thermometer is returned to ambient temperatures rapidly after freezing, there is a chance the bulb will crack. This breakage is caused by the mercury thawing in the capillary more slowly than the mercury in the bulb, creating a blockage of the expanding mercury. To avoid this, care must be taken to allow the mercury in the bulb to liquify at the same rate as the mercury in the capillary. To accomplish this, carefully place only the tip of the bulb into the cooling mixture (for example dry ice and alcohol). Hold the instrument vertical until all of the mercury is in the bulb, then allow the instrument to come back to ambient temperature while still holding the instrument vertically in the air. Do not jar the thermometer or hold it at an angle. Gas bubbles could develop in the bulb and cause inaccuracies. If gas bubbles form in the bulb, return it to us for repair.

ORGANIC LIQUID SEPARATIONS:

The liquid in organic filled thermometers can often be rejoined by using gentle centrifugal force. Swinging the thermometer in a slow arc causes the liquid to be pushed towards the bulb. Do not snap or shake like a fever or maximum registering thermometer. Also, for small separations at the top of the column, tapping the instrument against a finger or hand may break the contact of the liquid against the capillary wall and allow it to drain down into the main column.

If centrifugal force does not work, it is possible to heat the thermometer until the liquid reaches the expansion chamber at the top of the thermometer similarly as with the mercury thermometers above. Be very cautious when using a heating method with organic liquid thermometers. If the bulb breaks, the liquid inside is flammable.

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**My maximum registering thermometer looks separated and won't shake all the way down. Is it defective? Does this thermometer work differently from a regular thermometer?**

No, maximum thermometers will normally look separated below the thermometer's constriction. Capillary constriction allows mercury to rise when heated, but prevents it from receding until shaken down. To shake down, grasp thermometer near the top and with swinging motion with a snap, shake mercury below temperature to be measured. Thermometer cannot be shaken down below room temperature. Allow sufficient time for thermometer to attain maximum reading. Remove from heat and allow to cool to room temperature before reading. Errors may result if reading is taken before thermometer is cooled. A vacuum exists above the mercury column and the readings must be made with the thermometer in an upright position. **PLEASE NOTE: APPEARANCE OF MAXIMUM REGISTERING THERMOMETER IS DIFFERENT THAN A REGULAR THERMOMETER. CONSTRICTION APPEARS TO LOOK LIKE A MERCURY SEPARATION AND WHEN INVERTED THE MERCURY WILL RUN UP AND DOWN. THIS IS NORMAL.**

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