

Electronic Collections of Solved Problems in Physics and Physics Experiments



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Solved Problems

Collection of Solved Problems in Physics

Thermodynamics

About

Task number: 2110

Problem

Copper and zinc strips have the same length of 20 cm at a temperature of 20 °C.

a) What will be the difference in length of the strips at a temperature of 100 °C?

b) The strips were riveted together at 20 °C and formed a so-called bimetallic strip. Assume that it bends into an arc when heated. Determine which metal will be on the outer side of the arc and what will be the radius of the arc at 100 °C. Thickness of each strip is 1 mm.

Notation

Analysis

Substances expand when we increase their temperature. Different substances expand differently, that is why there will be the difference in the length of the two strips. As long as the strips are firmly riveted together so that they cannot move along each other, they will bend. The strip which expands less will be on the inner side, so in our case it will be copper. Since the thickness of the strips is constant, two curves differ in their length. The difference in the length of both arcs then most correspond to the difference in length caused by the different thermal expansion of the two metals.

Solution of a)

First, we express the length of both strips at temperature t .

$$l_{Cu} = l_0(1 + \alpha_{Cu}\Delta t)$$

$$l_{Zn} = l_0(1 + \alpha_{Zn}\Delta t)$$

We subtract one length from another:

$$\Delta l = l_{Zn} - l_{Cu} = l_0(\alpha_{Zn} - \alpha_{Cu})\Delta t$$

$$\Delta l = 0.2 \cdot (20 \cdot 10^{-6} - 17 \cdot 10^{-6}) \cdot (100 - 20) \text{ m}$$

$$\Delta l = 2.08 \cdot 10^{-5} \text{ m} = 0.208 \text{ mm}$$

Hint on b): How to determine the radius of the bimetallic strip?

Since the strips are firmly attached to each other, they will bend during heating. Consider that the length of the strip corresponding to the increased temperature is in the middle of the strip.

Expressing the arc's length

We will use the picture to calculate the radius of the arc. Since the strips are firmly attached to each other, they will bend during heating. Consider that the length of the strip corresponding to the increased temperature is in the middle of the strip.

Denote the radius of the smaller arc by r . Radius of the larger arc will be R :

$$R = r + \frac{d_1 + d_2}{2}$$

where d_1 and d_2 are the "magnified" thicknesses of both strips. The length of the circular arc can be determined as a product of the radius and angle φ (in radians):

$$l_{Cu} = r\varphi$$

$$l_{Zn} = (r + \frac{d_1 + d_2}{2})\varphi$$

We subtract the length of one arc from the other one and realize that their difference was equal the difference in the length of the strips that we expressed in part a) of this task.

$$\Delta l = l_{Zn} - l_{Cu} = (r + \frac{d_1 + d_2}{2})\varphi - r\varphi = \frac{1}{2}(d_1 + d_2)\varphi$$

We substitute the difference in lengths and the "magnified" thicknesses at the increased temperature:

$$l_0(\alpha_{Zn} - \alpha_{Cu})\Delta t = \frac{1}{2}(d_1 + d_2)\varphi$$

$$l_0(\alpha_{Zn} - \alpha_{Cu})\Delta t = \frac{1}{2}(d_1 + d_2)\varphi$$

From this equation we can express the unknown angle:

$$\varphi = \frac{2l_0(\alpha_{Zn} - \alpha_{Cu})\Delta t}{d_1 + d_2}$$

Finally, we substitute for given value:

$$r = \frac{l_0(1 + \alpha_{Cu}\Delta t)}{\varphi} = \frac{20 \cdot 10^{-2} \text{ m} \cdot (1 + 17 \cdot 10^{-6} \cdot 80)}{\frac{2 \cdot (20 \cdot 10^{-6} + 17 \cdot 10^{-6}) \cdot 80}{2 \cdot (20 \cdot 10^{-6} + 17 \cdot 10^{-6}) \cdot 80}}$$

$$r = 0.9647 \text{ m} \approx 96 \text{ cm}$$

Answer:

The difference in the length of the two strips will be about 0.2 mm, and the bimetallic strip will bend into the arc with the radius of approximately 96 cm.

History

- started in 2006 as small-scale project
- nowadays published several hundreds of tasks
- 2015 new web interface
- started 2016, uses the same interface
- a significant increase in traffic during the lockdown periods in 2020–2022

Motivation

- assist students in self-study and during online education
- support teachers by quality and verified materials
- lead to active and independent thinking
- help for weaker students, challenges for advanced students

Special designed structure

- detailed and structured solutions
- carefully tested procedures
- qualitative analysis of the problem
- sample results (graphs, photos, video shots)
- structured hints and their solution
- methodological and technical notes
- comments, cross-linking tasks and experiments

Sorting and filtering

- Difficulty**
- from lower secondary to university (4 levels)
- from nursery school to university (4 levels)

Type

- solution by reasoning, graphical tasks, unusual tricks, complex tasks
- qualitative or quantitative experiment

Cognitive processes

- analysis, synthesis, sorting, induction, deduction, transformation, proving, ...

Technical parameters

- simple, common or special equipment
- preparation: under 3 min, 3–10 min, above 10 min
- duration: under 3 min, 3–10 min, above 10 min

Fulltext search

Content

	Problems		Experiments	
	CZ	EN	CZ	EN
Mechanics	235	108	7	1
Electromagnetism	282	93	52	13
Thermodynamics	158	84	75	55
Optics	67	26	30	12
Others	211		6	

Physics Experiments

Collection of Physics Experiments

Thermodynamics

About

Show experiment

Experiment number: 2114

Goal of experiment

The goal of this experiment is to show the behaviour of bimetallic strip during temperature changes.

Theory

Thermal expansion

Thermal expansion is a property of most substances. As temperature rises, the dimensions of most materials increase and vice versa. This feature is used in bimetallic.

Bimetallic

Bimetallics are made of two different metals that are firmly joined together. These metals must have different thermal expansion coefficients. When the bimetallic is in the shape of a strip, it will bend with changing temperature.

At a certain temperature at which the two metals were joined, they are of the same length and the bimetallic is straight.

With increasing temperature, the dimensions of the two metals increase by a different value, resulting in bending. When the temperature decreases to the initial temperature, the bimetallic again becomes straight.

If the bimetallic is cooled, both metal strips lengths will decrease by a different value, and the bimetallic will bend towards the opposite side than when it is heated.

Bimetallic applications

Bimetallic is used, for example, as a thermostat, an electromechanical thermostat (for example in iron or infrared heaters), or as a part of electrical circuit breaker.

To calculate the lengths of the metal strips depending on the temperature, see **Bimetallic**.

Tools

- bimetallic
- bimetallic holder (after warming the bimetallic is very hot and it is not advisable to hold it in your hand)
- candle
- lighter
- ice

Procedure

- Place the bimetallic into the holder.
- Put the candle about 2-3 cm below the bimetallic.
- Light the candle and watch the bimetallic bend.
- After a while, put the candle away and watch the bimetallic straighten.
- After the bimetallic strip is straight, cool it with two ice cubes.
- Observe that bimetallic bends now to the opposite side than when heated.

Observed result

When heated, the bimetallic strip bends.

When we take away the heat source, the temperature of bimetallic begins to decrease and it gradually straightens.

When the bimetallic is cooled by the ice, it bends to the opposite side than when it is heated.

Pedagogical notes

We can make a bimetallic strip at home. We need scissors, glue, a piece of paper and a piece of aluminium foil of the same size.

We glue the paper and the aluminium foil and press together. Wait for the glue to dry and cut a rectangular strip. When we heat our "bimetallic" above the candle, the aluminium strip will extend more than the strip of paper and the "bimetallic" bends.

Short videos

- published at separate YouTube channel
- almost 400 short clips (usually not exceeding 90 seconds in length)
- provide teachers a quick understanding of what to expect in the experiment



PISA problems

- science tasks used within the Programme for International Student Assessment (PISA)
- effort to make released tasks accessible to a wider range of teachers and students
- scientific literacy development, independent of content knowledge
- currently 27 tasks including 3 tasks with interactive elements

Otázka 4

Vycházej z informací uvedených níže a proveď simulaci k získání potřebných údajů. Daníel vidí vzdálené přední okraje, ale blízké přední okraje vidí rozmazaně. Které nastavení by měl Daníel vidět blízké přední okraje ostře? Nezapomej vybrat **jednu nebo více** možností.

Objem kapaliny v čáře

Daleko Uprostřed Blízko

Vzdálenost od stromu

Objem kapaliny v čáře

Blízko Uprostřed Daleko

Vzdálenost od stromu

Spustit

Reset

Interactive components

- prepared mainly in GeoGebra
- accompanied by small tasks
- show assignment setup
- deepen readers' understanding
- animate solution
- show result with different assigned parameters

construction of the hypocycloid (interactive geometric model)

adding magnetic induction of four wires with constant current (applet)

assigned situation (3D rotating geometric model)

redrawing shape of DC circuit (animation)

equipotentials for two different charges (visualisation of more difficult situation)

Users per day

