

Electronic Collections of Solved Problems in Physics and Physics Experiments

Zdeňka Koupilová, Petr Kácovský, Marie Snětinová, Dana Mandíková Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

of Metals

Bimetal

with Hole

Liquids (1)

 \rightarrow

Solved Problems

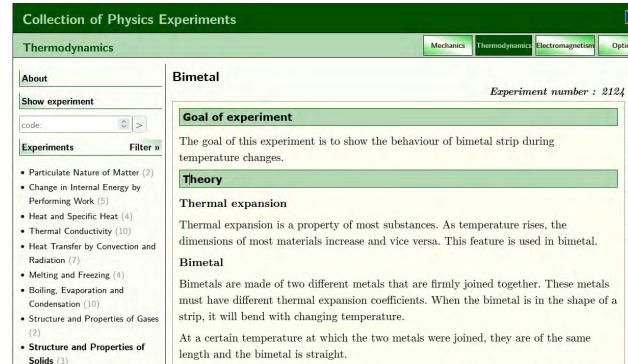
Thermodynamics		Mechanics	Thermodynamics Electricity magnetis	Ontics	Small-sca physics
About Show task	Bimetal Copper and zinc strips have the		and the second	Task number:	2110
Tasks Task • The basics (5) • Internal energy, work and (17) • Ideal and real gas (22) • Thermodynamics laws (1 • Solids and liquids (27) • Mine Shaft Elevator (1 • Hook's Law and Linea Expansion (L3)	a) What will be the difference b) The strips were rivetted tog Assume that it bends into an a outer side of the arc and what strip is 1 mm. 2)	in length of the strip gether at 20 °C and f arc when heated. Det	os at a temperature o formed a so-called bi termine which metal the arc at 100 °C. 7	of 100 °C? metallic strip. will be on the	e
 Laboratory Problem (I Small cork boat (L3) Wood in Benzene (L3) Apparent Coefficient or Thermal Expansion of 	Notation Analysis				

History

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

Motivation

Physics Experiments



PISA problems

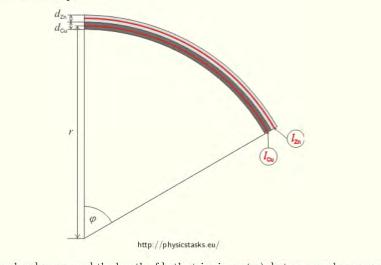
- science tasks used within the Programme for International Student Assessment (PISA)
- effort to make released tasks accessible to a wider range of teachers and students
- scientific literacy development, independent of content knowledge
- currently 27 tasks including 3 tasks with interactive elements

Otazka 4			

Change of Volume of a Body When Being Heated (L2) Diameter Increase of Cylinder When Being Heated (L2) Mercury in a Tube (L3) Thermal expansion of brass halls (12 Change in the Metal Plate's Size during Heating (L2) • Bimetal (L Clock Drift at Higher Temperature (L2) Two connected soap bubbles Capillary action between glass plates (L3) Soap Film in a Wire Frame with a Movable Crossbar Oil Pipetting (L2) Height of Water in a Capillar Tube (L3) • Capillary (L2) • Capillary and a rod (L3) Bar Expansion During Its Cooling (L3) Capillary with a Sealed End Capillary in an Accelerating Elevator (L3) Wire Diameter Difference Heating of Steel Bar (L3) Calculation of Minimal Wate Volume (L4) Changing the Melting Point Termodynamics potencials

differently, that is why there will be the difference in the length of the two strips. As long as the strips are firmly rivetted 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 must 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 a $l_{Cu} = l_0 \left(1 + \alpha_{Cu} \Delta t \right)$ $l_{Zn} = l_0 \left(1 + \alpha_{Zn} \Delta t \right)$ We subtract one length from another: $\Delta l = l_{Zn} - l_{Cu}$ $\Delta l = l_0 \left(1 + \alpha_{Zn} \Delta t \right) - l_0 \left(1 + \alpha_{Cu} \Delta t \right)$ $\Delta l = l_0 \left(\alpha_{Zn} - \alpha_{Cu} \right) \Delta t$ $\Delta l = l_0 \left(\alpha_{Zn} - \alpha_{Cu} \right) \left(t - t_0 \right)$ Finally, we substitute for numerical values: $\Delta l = l_0 \left(lpha_{Zn} - lpha_{Cu}
ight) \left(t - t_0
ight)$ $\Delta l = 0.2 \cdot (30 \cdot 10^{-6} - 17 \cdot 10^{-6}) \cdot (100 - 20) \text{ m}$

> $\Delta l = 2.08 \cdot 10^{-4} \,\mathrm{m} = 0.208 \,\mathrm{mm}$ 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.



We have already expressed the length of both strips in part a), but we can also express it through angle φ and the desired radius r. Therefrom we can determine the radius r.

Note: When the temperature increases, the thickness of the strips also increases. However, this effect has very little impact on the result, therefore you may ignore it.

Expressing the arc's lengths

Solution of b)

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.



- assist students in self-study and during online education • support teachers by qualite 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 \rightarrow
- qualitative analysis of the problem
 - sample results (graphs, photos, video shots) \rightarrow
- structured hints and their solution
 - methodological and technical notes \rightarrow
- comments, cross-linking tasks and experiments

Sorting and filtering

Difficulty

from lower secondary to university (4 levels) from nursery school to university (4 levels) \rightarrow

Туре

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

Cognitive processes

 Thermal Volumetric Expansio 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 bimetal again becomes straight Heating of Aluminium Plate If the bimetal is cooled, both metal stripes lengths will decrease by a different value, and Structure and Properties of the bimetal will bend towards the opposite side than when it is heated. Bimetal applications Bimetal is used, for example, as a thermometer, an electromechanical thermostat (for example in irons or infrared heaters), or is a part of electrical circuit breaker. To calculate the lengths of the metal strips depending on the temperature, see Bimet Tools • bimetal \circ bimetal holder (after warming the bimetal is very hot and it is not advisable to hold it in your hand) candle lighte



Procedure

1. Place the bimetal into the holder 2. Put the candle about 2-3 cm below the bimetal 3. Light the candle and watch the bimetal bend. 4. After a while, put the candle away and watch the bimetal straighten. 5. After the bimetal strip is straight, cool it with two ice cubes 6. Observe that bimetal bends now to the opposite side than when heated



Observed result

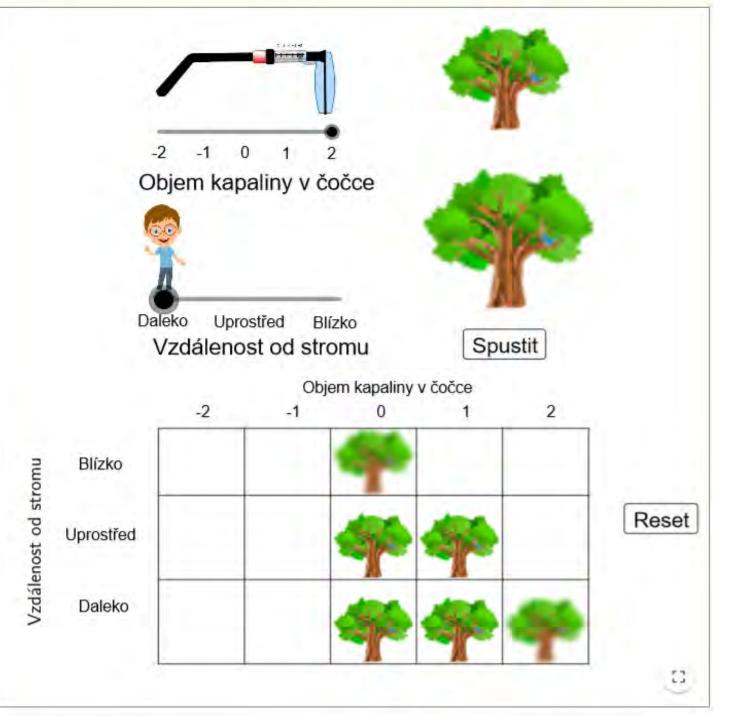
When heated, the bimetal stripe bends. When we take away the heat source, the temperature of bimetal begins to decrease and it gradually straightens.

When the bimetal is cooled by the ice, it bends to the opposite side than when it is



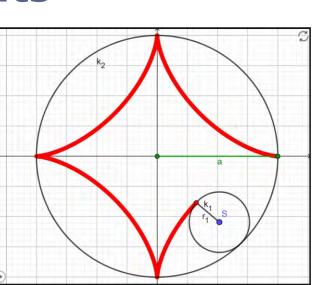
Vycházej z informací uvedených níže a proveď simulaci k získání potřebných údajů. Daniel vidí vzdálené předměty ostře, ale blízké předměty vidí rozmazaně.

Které nastavení brýlí umožní Danielovi vidět blízké předměty ostře? Nezapomeň vybrat jednu nebo více možností.



Interactive components

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





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).

> $l_{Cu} = r\varphi$ $l_{Zn}=(r+rac{d_{Zn}}{2}+rac{d_{Cu}}{2})arphi$

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

 $\Delta l=l_{Zn}-l_{Cu}=(r+rac{d_{Zn}}{2}+rac{d_{Cu}}{2})arphi-rarphi=rac{1}{2}(d_{Zn}+d_{Cu})arphi$

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

 $l_0\left(lpha_{Zn}-lpha_{Cu}
ight)\Delta t=rac{1}{2}[d(1+lpha_{Cu}\Delta t)+d(1+lpha_{Zn}\Delta t)]arphi$

 $l_0\left(lpha_{Zn}-lpha_{Cu}
ight)\Delta t=rac{1}{2}d[2+(lpha_{Cu}+lpha_{Zn})\Delta t)]arphi$

From this equation we can express the unknown angle:

 $2l_o(\alpha_{Zn}-\alpha_{Cu})\Delta t$ $\varphi = \frac{1}{d[2 + (\alpha_{Cu} + \alpha_{Zn})\Delta t)]}$

Finally, we substitute for given values:

 $r = rac{(1+17\cdot 10^{-6}\cdot 80)[2+(30\cdot 10^{-6}+17\cdot 10^{-6})\cdot 80]}{10^{-3}} \cdot 10^{-3} \, \mathrm{m}$ $2 \cdot (30 \cdot 10^{-6} - 17 \cdot 10^{-6}) \cdot 80$

 $r \doteq 0.9647 \,\mathrm{m} \doteq 96 \,\mathrm{cm}$

Note: If we look more closely at both expressions in brackets in the numerator of the resultant fraction, it is obvious that we can omit the terms which contain the thermal coefficients α_{Zn} and α_{Cu} . The first expression in brackets is related to the change in length of one strip and the second expression in brackets corresponds to the change in the strip's thickness. On the contrary, we cannot do any omission of the expression in brackets in the denominator, because both terms are of a similar magnitude. This expression is related to the difference in the linear extension of both metals. This will give us a simpler relation:

$$r \doteq rac{(1+\dots)[2+\dots]}{2(lpha_{Zn}-lpha_{Cu})\Delta t} \, d = rac{d}{(lpha_{Zn}-lpha_{Cu})\Delta t}$$
 $r \doteq rac{10^{-3}}{(30\cdot 10^{-6}-17\cdot 10^{-6})\cdot 80} \, \mathrm{m} \doteq 0.9615 \, \mathrm{m} \doteq 96 \, \mathrm{cm}$

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.

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

Technical parameters

simple, common or special equipment \rightarrow

- preparation: under 3 min, 3–10 min, above 10 min \rightarrow

duration: under 3 min, 3–10 min, above 10 min \rightarrow

Fulltext search

Content

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

Summer

holiday

is not bending anymore, put the candle aw 🛛 Vysílá:= 🕑 YouTube a 📘 **Pedagogical notes**

We can make a bimetal 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 "bimetal" above the candle, the aluminium strip will extend more than the strip of paper and the "bimetal" bends.

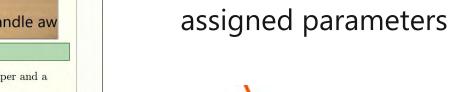


• published at separate YouTube channel

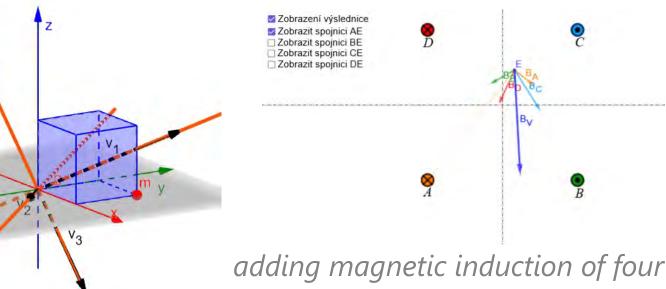
• provide teachers a quick understanding

• almost 400 short clips (usually not

exceeding 90 seconds in length)

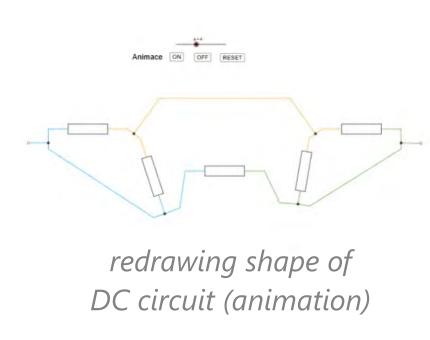


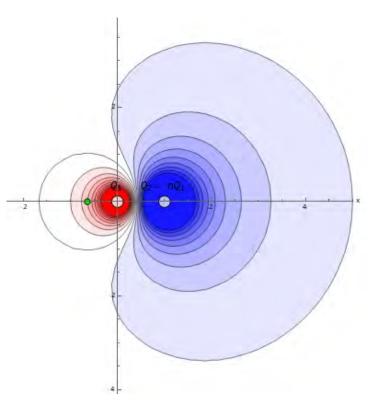
construction of the hypocycloid *(interactive geometric model)*



wires with constant current (applet)

assigned situation (3D rotating geometric model)





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

Users per day

in Czech

Schools lockdown (in Czechia) Schools lockdown (in Czechia)

Summer holiday

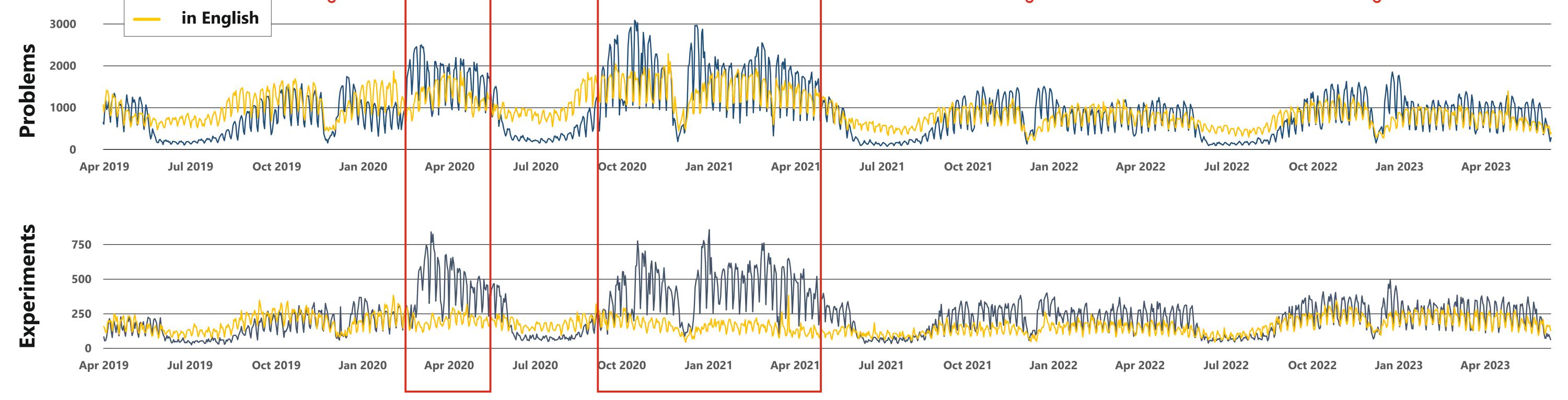
Short videos

of what to expect

in the experiment

Summer holiday





https://physicstasks.eu/

sbirka@kdf.mff.cuni.cz

http://physicsexperiments.eu/