Thermo-Cam at Topic Week

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Abstract

The so-called topic week, this newly established education form, provided the framework for a project with a scientific infrared camera. The pupils investigated a lot of known experiments and phenomena in the classroom, but acquired new knowledge as well. They shot short videos about transformation of mechanical energy into heat, gas laws, different forms of heat transfer, endothermal and exothermal chemical reactions, and other topics. The experience of working in a team with such an exciting, interesting, motivating and modern device had several benefits in physics education.

1. Introduction

The crisis of education, especially in the education of science, stimulates the teachers to find new educational methods and to try new methodology. This is supported by tenders that help the aims of the educational renewal with more or less success.

Within the framework of the introduced tender a so-called topic week was organized at our school. Sixteen teachers introduced sixteen different topics for the 11^{th} grade students, to which they could apply freely according to their interest. After a two week preparation period the groups of five to ten students worked freely in a self-organized way for three school days without regular lessons. The students were supported mainly by their teachers' remote control. On the fourth day the groups presented their projects to the whole school.

Only two of the sixteen topics were devoted to natural sciences. One of these two topics was the "Thermo-cam project". According to our original plans we should have borrowed a simple handy camera to make the thermal map of the school inside and outside. But we did not manage to find a handy camera. Eventually, one of our alumni lent to us an extremely sensitive and high resolution instrument, which had been developed for scientific research. There were 15 pupils in the group. At the beginning they were not very motivated to work on the project – right until the first glimpse on the picture of the camera.

The paper is organized as follows. In *Section 2* the main features of the camera are presented as well as the preparation for the topic week by the students. *Section 3* contains the case studies of several phenomena investigated with the camera. In *Section 4* we summarize the conclusions.

2. The camera

This camera is an extremely sensitive device. Its accuracy is 0,1 °C, the video rate is 50 megapixel per second. It has four semiconductor detectors for the different temperature ranges. The detectors must be cooled, so there are permanently working thermoelectric and

Stirling coolers built into the machine. The cam does not have a display of its own, but has its own computer with the camera's software.
So the camera is fragile and not easy to move. Therefore, given up our original plan of making a thermal map, we made movies of different experiments and phenomena in a classroom.

When making films with the camera, the different temperatures of the real world are transformed into different colours by the camera's software. We can choose from several colour schemes to get the most impressive picture. Every shot has a colour bar on the right side of the screen. It shows the colour scale according to the temperature scale.
The built-in software of the cam is also suitable to plot graphs. The cam continuously measures the maximum/minimum/average temperature of a chosen area, which is indicated by a small rectangle on the video. The temporal evolution of these data is plotted in a graph in a chosen time interval

As I did not dare to give the very expensive camera to fifteen young students working freely without teacher control, in this group the students always worked under my guidance. Nevertheless, this way we gained a lot of common experiences, discovering together the possibilities of the camera. And this was a real pedagogical success…

On the left side of Figure 1. the thermopicture of the thermogroup can be seen. We can observe that our noses are colder than the rest of our face and the amazing fact that eyeglasses are not transparent for infrared rays. The right side shows our cooling marks on the bench after we stood up.

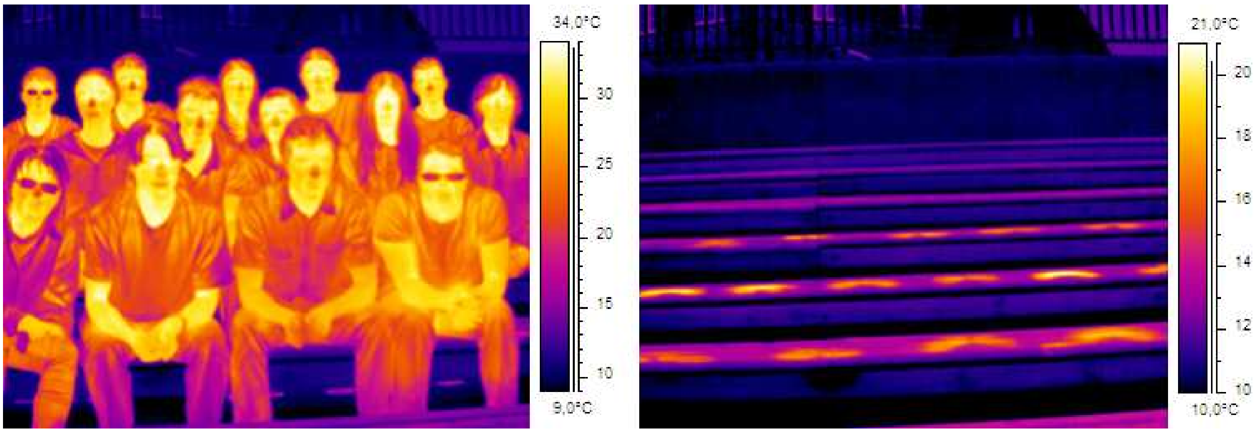

Figure 1. The thermopicture of the thermogroup (left) and our cooling mark on the bench after standing up (right)

During the preparation period of the project the students translated an English article, which described the basic features, formation and applications of infrared technology. [1] Then the pupils were to pick phenomena and experiments which they thought worth investigating with the thermal cam. The topics that inspired them are collected in the Case studies section

3. Case studies:

Transformation of mechanical work into heat

There are several well known examples of the phenomenon when the mechanical energy is transformed into heat by friction or deformation. [2] Sometimes we can feel this in our palms, but mostly we only anticipate that it must happen this way. Such phenomena became visible with the help of the sensitive camera.
Below I am presenting three of our many experiments.

First we investigated the blocking brake of a cyclist on linoleum surface. The hot brake imprint is clearly seen in the picture. Note that the sharp edge of the stripe is caused by the poor heat conductivity of linoleum. It is amazing that friction warms up the linoleum to over 60°C (see Fig. 2.). The software shows the cooling curve as well. The little spots on the curve are taken periodically in time. It is impossible to fit a simple function on these data because the cooling process is a mixture of radiation and heat conduction at the same time.

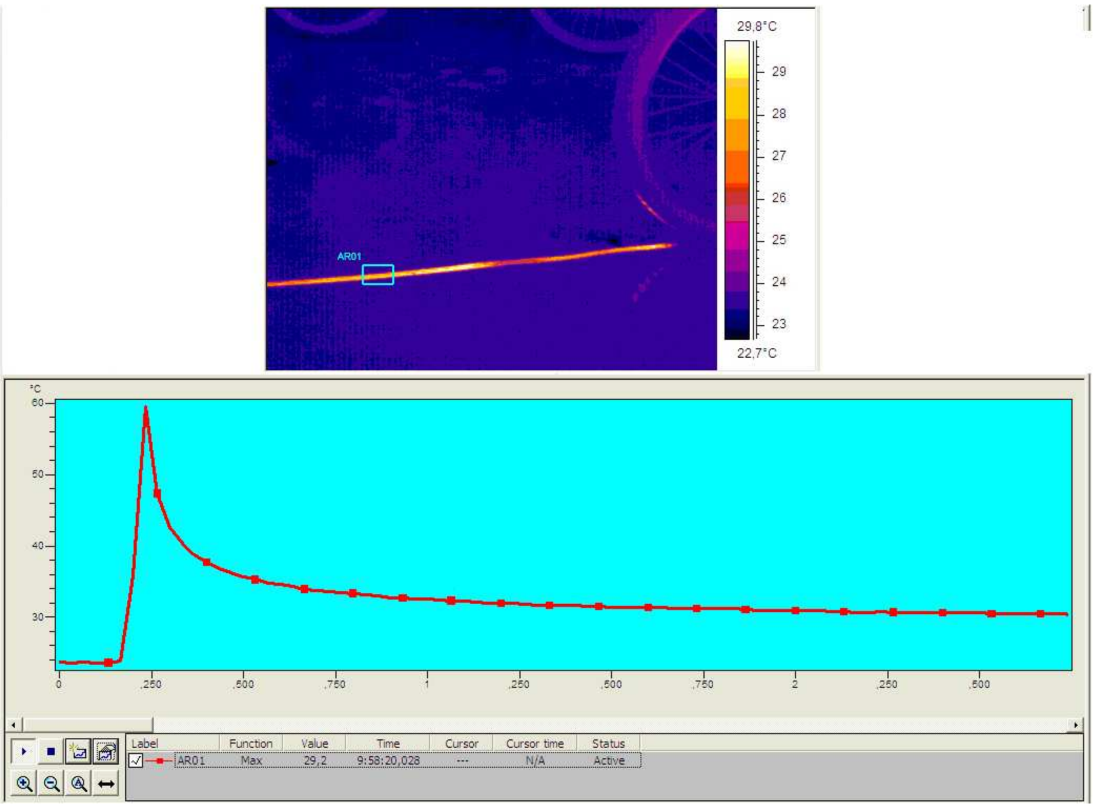

Figure 2. Thermopicture of the warming up and cooling down of the linoleum after blocking the brake of a bicycle. The graph shows the maximum temperature of the area indicated by the little rectangle

In another demonstration the pupils were hammering away at a lead pipe (see Fig. 3.). They knew well that it should warm up, moreover they were able to calculate the rise of temperature, but we had not seen before how the warming process really happens. The planished lead pipe warmed up by circa 3-4 °C.

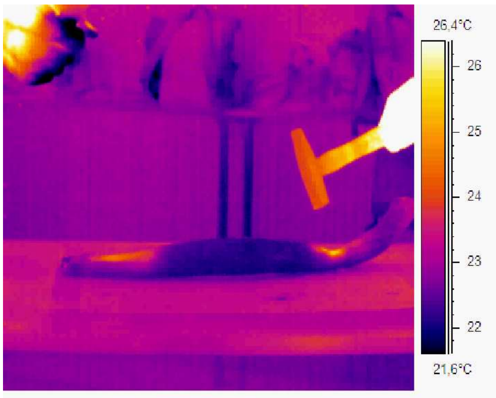

Figure 3. Warming up of a lead pipe due to hammering away at the ends with two hammers

The bouncing ball caused surprise, too. It is well known that its collision is not perfectly elastic, so the dissipated mechanical energy transforms into heat. This effect becomes visible with the help of the sensitive camera (see Fig. 4.).

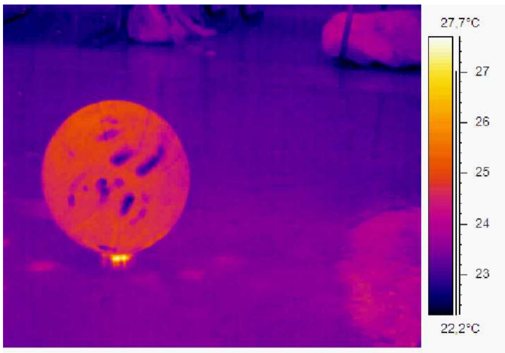

Figure 4. Thermopicture of the warming up of the colliding surfaces by circa 2-3 °C due to the not perfectly elastic collision of the ball

Electricity

The students had already studied electric heating. [3] This can be demonstrated with the thermo cam, for example, in cases when the warmed up resistors are not glowing. Several pictures were taken about resistors connected in different ways. It was interesting to observe and also to calculate that among resistors connected in series the largest warmed up the most, while among resistors connected in parallel, the smallest did.

The warming of an energy saving fluorescent lamp and that of a traditional bulb was also investigated. Their light is very similar in the visible region. (see the left side of Figure 5.) However, their infrared images are very different; the traditional bulb warms up strongly, while the fluorescent lamp remains cold. (See the right side of Figure 5.) (On the infrared picture you can also see the mirror image of the hot incandescent wire on the surface of the cold fluorescent lamp.)

Figure 5. An energy saving and a traditional bulb in visible (left) and in infrared (right) light

Gas laws

The changes in the thermodynamical state of gases are mostly coupled with the change in their temperature.[4.] We wanted to demonstrate this phenomenon via thermo pictures.

The most spectacular investigation was the pumping of a ball. The pump compresses the air adiabatically, so it warms up (see Fig. 6.). In the picture, and also in the graph below, there can be seen that the outlet tube of the pump (red curve) warmed up to the highest temperature. The compressed hot air, coming out from the pump's cylinder, warmed up the tube as demonstrated by the red curve of the bottom panel. The farther sections of the tube (blue curve) warmed up less and the ball (green curve) hardly changed its temperature since the heat loss of the air is considerable.

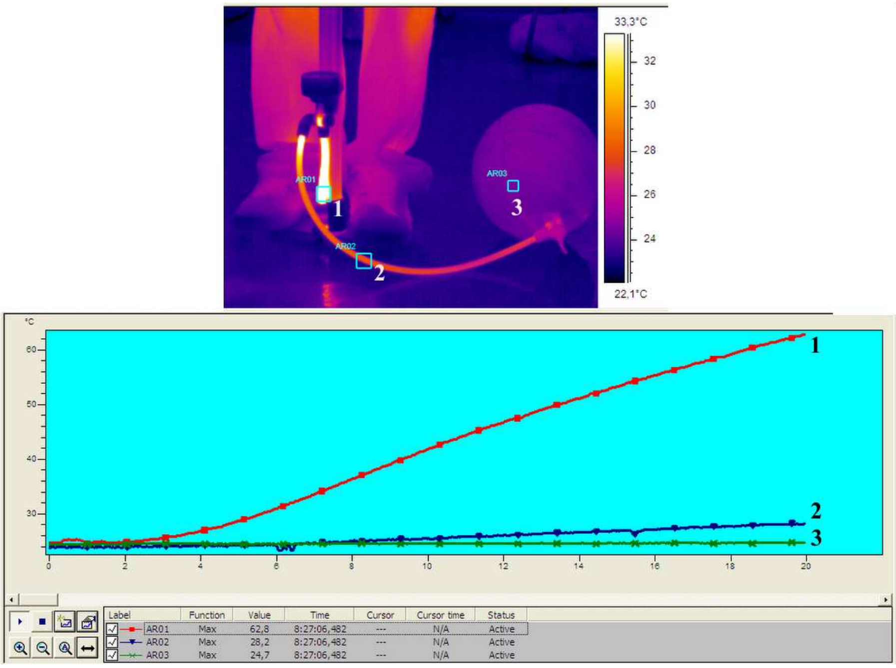

Figure 6. Thermopicture (upper panel) of the warming up during adiabatic compression while pumping a ball. The three graphs show the temperature of the enumerated area of the picture.

Phase transitions [5]

The investigated phenomena were mostly based on evaporation. One of the most surprising case was that of the thermal graffiti written on the board by mean of a deodorant spray. The ejected, rapidly evaporating gas, which contained some alcohol, cooled down its vicinity by 1-2°C. In visible light the inscription disappeared within a few seconds, but the warming up of the board required at least 20 minutes, so the thermo cam "saw" the text for a while (see Fig 7.).

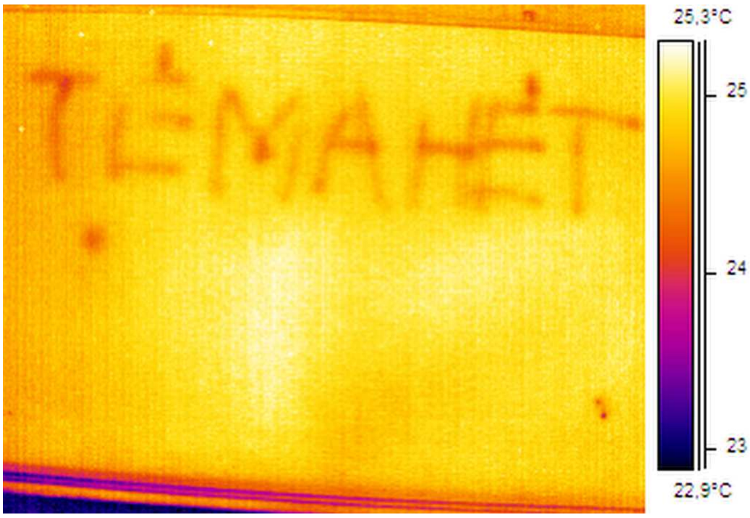

Figure 7. Thermo-graffiti written by deo-spray.

Heat transfer

We have investigated all the three forms of heat transfer: convection, conduction and radiation. [6]

A spectacular movie was shot about a radiator, which was cold when its tap was opened. The graph of Figure 8. shows the temporal change of the temperature at a few selected points of the radiator (marked on the left panel). The rates of change of temperature at these points differ from each other: farther away from the tap the rate of change is smaller because here the start of warming is caused by moderately warm water. We can also see the cooling down of the out-coming tube of the radiator. It was warm initially, but cold water flowing out from the radiator caused its temperature to decrease.

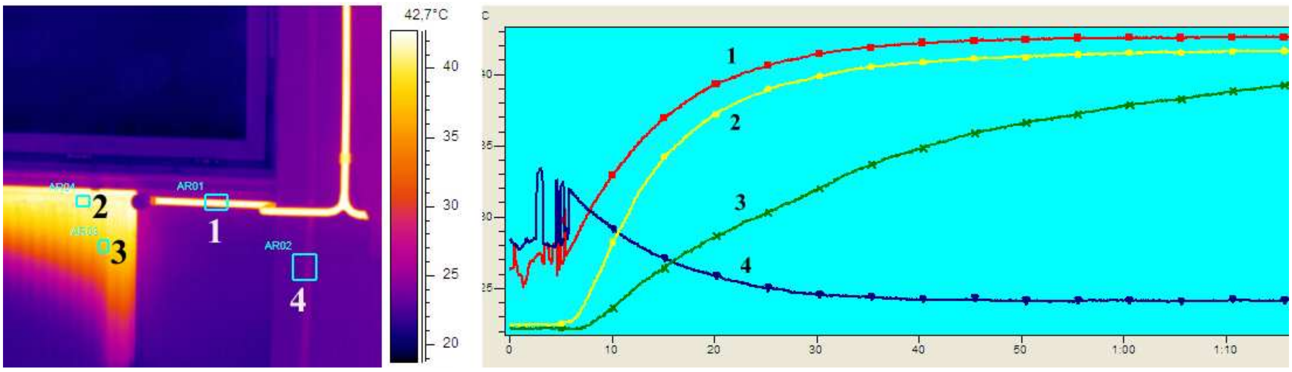

Figure 8. Heat convection in a radiator after opened its tap. The graphs show the temperature of the counted areas

The palm print of a cold-handed boy proved to be an excellent example of heat conduction. The infrared print was visible on several pages of a book below his palm, much after its removal (see Fig. 9.).

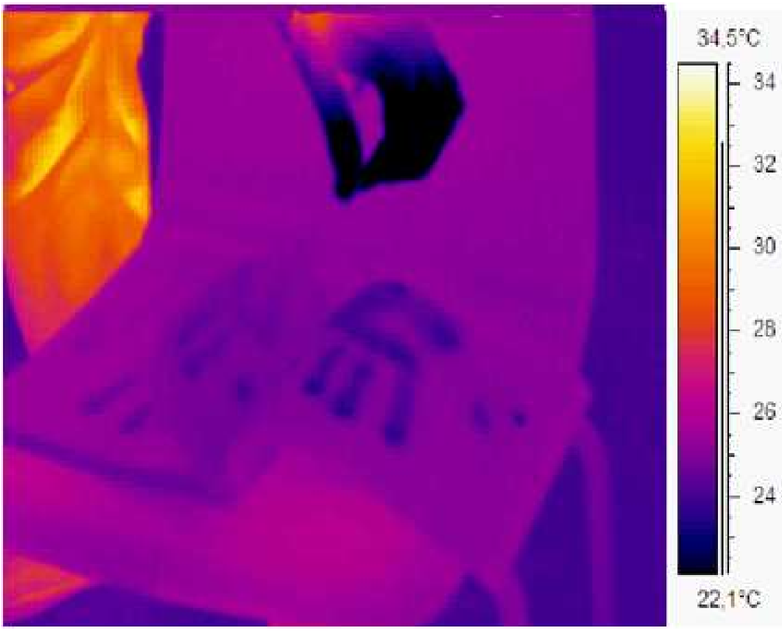

Figure 9. A cold palm and its thermo-prints on pages of a book

Heat radiation was investigated by means of an electric radiator. It is well known that radiation warms up black bodies rather than white ones. This can clearly be seen well in the experiment in which a black and a white sheet of paper were radiated for a while. These sheets were identical except for their colour. We used the black and white mode of the thermal cam. It was really funny to compare the sight of the warmed up sheets in visible light (where black is black; white is white) and the thermo pictures (where the warmed black appears white; the relatively cold white is black; see in Fig. 10.).

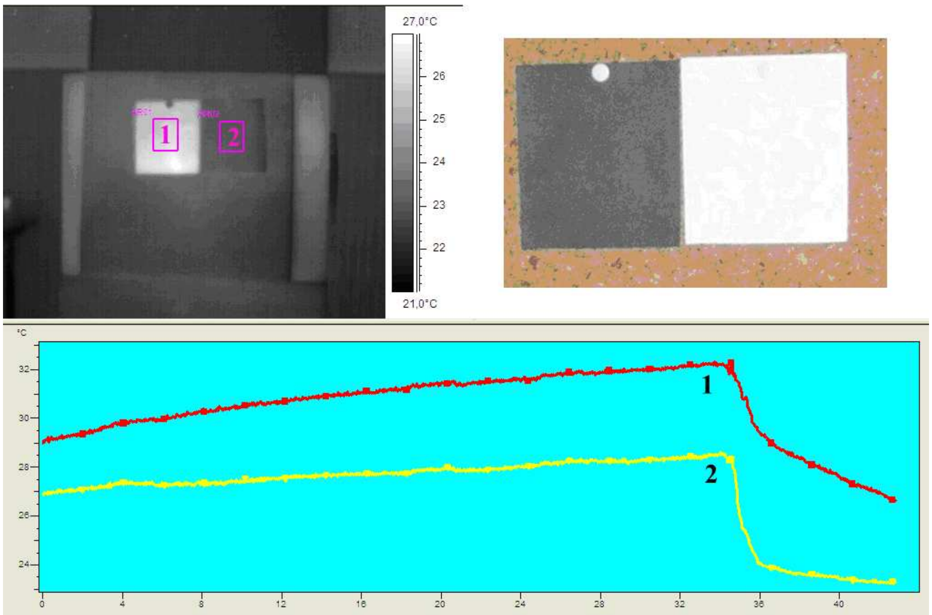

Figure 10. Thermopicture (left) and visible light photograph (right) of warmed up black (1) and white (2) papers and their temperature graphs (bottom)

Heat optics

We learned from the texts translated during the preparation period that infrared optics is the same as the optics of visible light. But it was highly surprising to see which materials could be used as a good mirror of infrared rays.
With the help of the thermo cam we hoped to observe the warming up of the pupils' bodies after exercises in the gym. Instead we observed the shocking fact that the green linoleum cover of the gym floor behaved in the infrared region as a plane mirror (see Fig.11.).

Figure 11. The matt linoleum cover of the floor behaves as a plan heat mirror in the gymnasium

This is why we went on seeking thermally reflecting surfaces. Metals were found to be good infrared reflectors even if they are matt in visible light. One of the good examples was an old brass mirror from the store room of our physics department. Earlier, it was used for focusing thermal rays. Very clearly the cam showed an inverted, diminished, real image in the mirror (see fig.12.).

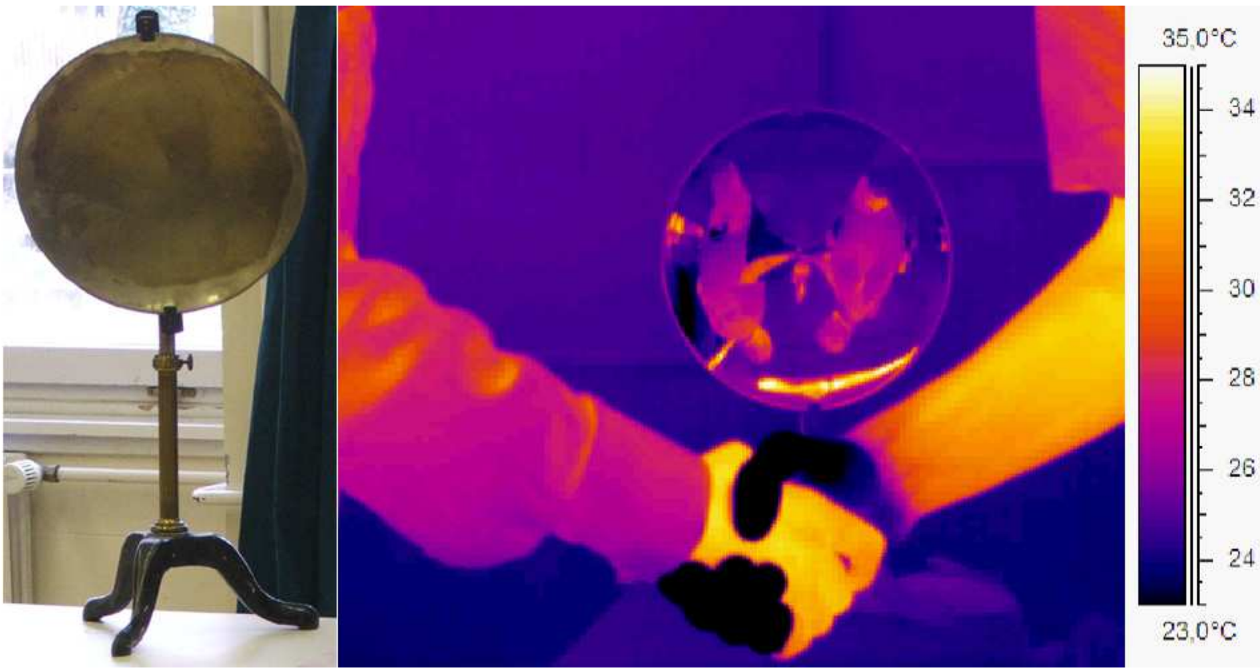

Figure 12. An old matt concave brass mirror (left) and the inverted, diminished, real image in it in infrared (right)

Chemical reactions

We investigated exothermal and endothermal chemical reactions as well.
When mixing ammonium-rhodanid and barium-hydroxide, a nice cooling effect was found: the temperature decreased by below –10°C from room temperature. [8]
The most spectacular warming up process was the solution of sulphur-acid in water, which happens even if the sulphuric acid should extract the water from the material to which the acid is dropped. We had written the chemical formula of sulphuric acid on a sheet of paper with the help of a glass rod merged into the acid earlier. The formula warmed up (see Fig. 13.).

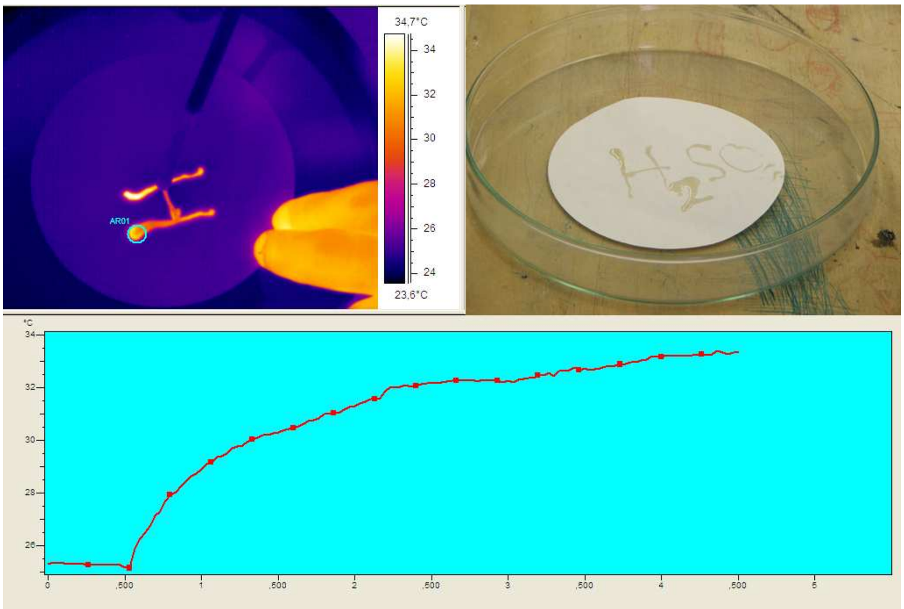

Figure 13. Exothermal reaction of sulphur-acid with water extracted from paper infrared Thermopicture of the inscription's first letter (left), visible range picture of the full formula (right), and the temperature graph of the marked by a circle in the upper panel (bottom)

Traffic

We were shooting photos of the traffic of the street for a while. We could observe the position of the engine in the bodies of the cars and we could also see the warmed up brakes and tires. It was clear that the most effective brakes are the disc brakes in the front of the cars because these brakes warmed up the most (see Fig. 14.).

Figure 14. Thermopicture of a car with warm front disc brakes

Pictures of school life, portraits

It was evident to take photos and make movies of each other and about some moments of the school life. [10] The photo of the "chocolate coated cottage cheese stick" slot-machine showed, e.g., that its front side was cold, but the back of it was very warm. The lunch at the school cafeteria was also investigated. The soup was found too hot and the meat, in contrast to it, too cold (see Fig. 14.).

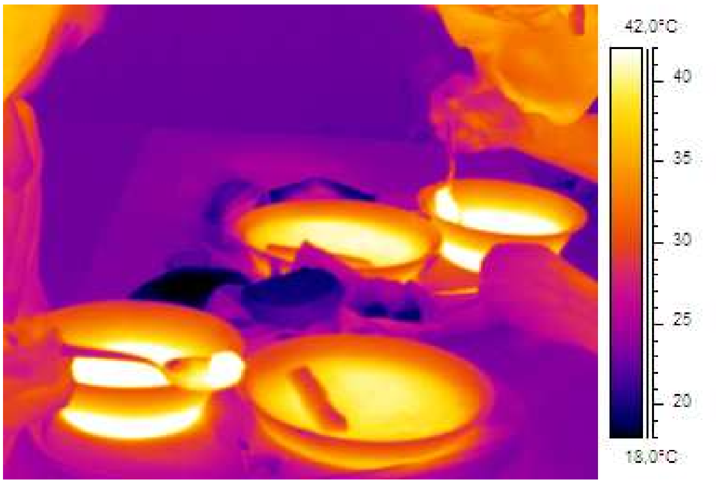

Figure 14 Thermopicture of the lunch at the cafeteria

The students also shot a hand wash. It was shocking that the water being transparent in visible light became opaque in infrared. Washing hands with cold water appeared as if the pupils put their hands in black pitch (see Fig. 15.).

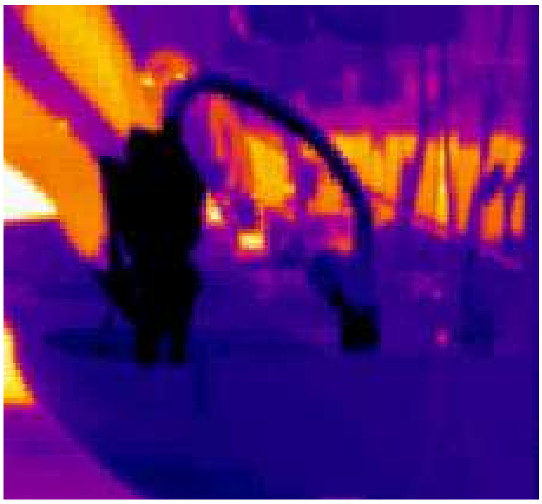

Figure 15 Thermopicture of handwash with cold water The water appears opaque in infrared

The website

During the three day project the students shot more than 50 movies. They selected the pictures, cut and edited the films. The oral presentation of their project was spectacular, exciting. Many of their schoolmates came to see it. The thermogroup considerated their project very successful. After the school presentation the pupils did not want to go home because they wished to stay together with the experiences of the previous days for a while. At that time they decided to create a web-site on the Internet about the project, which contains not only the files, movies, photos, but the explanations, too.

The web-site has been made: http://berzsenyi.hu/~hokamera

4. Conclusions

What has been the benefit of this project? A direct result is the set of short movies of the observed phenomena, which are available on our website now.

This project had some ulterior benefits, too. It was an impressive experience of physics for all of us. Everything that could be seen had been known, but only due to the teachers´ instructions. Now it had become visible by naked eye, so the pupils could experience the power and efficiency of physics. Such a camera is a state-of-the-art scientific device. It can measure and visualise the temperature and can plot diagrams as well. The pupils gained insight into the work with such a modern scientific instrument. The students practised new skills, worked together enthusiastically. It was an exciting, never-to-be-forgotten week for the students and for the teacher as well.

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