

Measuring the coefficient of emissivity using thermal radiation equipment SNR V-1.4 SL

A Malik*, R Zakwandi, S Nurfalah, N Nurhayati, C Rochman and D Nasrudin

Prodi Pendidikan Fisika, UIN Sunan Gunung Djati Bandung, Jl. A.H. Nasution No. 105, Bandung 40154, Indonesia

*adammalik@uinsgd.ac.id

Abstract. Heat is an energy that can propagate kinetically or radiationally. The thermal radiation is influenced by several factors such as surface shape, material properties, cross-sectional area and material emissivity. This study aims to develop thermal radiation equipment SNR V-1.4SL able to overcome the limitations of laboratory equipment in schools, especially on the topic of radiation heat transfer. The thermal radiation equipment SNR V-1.4SL was made from easily accessible and environmentally friendly materials and equipment. The experimental results of the thermal radiation equipment SNR V-1.4SL can clearly illustrate the phenomenon thermal radiation and the equipment SNR V-1.4SL can be used anytime and anywhere without depending on environmental conditions. The results of the overall test show the value of the efficiency of the equipment SNR V-1.4SL is still relatively low. In general, thermal radiation equipment SNR V-1.4SL

1. Introduction

The heat transfer is a symptom caused by the temperature difference between the two systems. The heat flow comes from systems that have higher temperatures to lower temperatures. The transfer of heat from one system to another is the impact on the law to zero thermodynamics which states that in a state of equilibrium all objects to the system had the same temperature [1]. The process of heat transferred can be through three ways, namely conduction through the solid medium, convection through fluid medium and radiation by the radiation. The process of conduction and convection heat transfer is a significant form of mechanical displacement during the heat transfer process following motion rules in mechanics. For example the heat transfer process by conduction will be fulfilled if there is contact between objects, while convection requires a fluid substance to move the heat [2]. Unlike the process of radiation that in heat transfer does not require a medium. The radiation heat transfer is also a form of the nature of light as an electromagnetic wave [3]. The process of radiation heats to transfer is influenced by several factors including 1) cross-sectional area, 2) object color, 3) heat receiving time, 4) source heat intensity, 5) type of heat receiver.

Laboratory activities are a must prepare for teachers to be implemented by students. Laboratory activities provide benefits and aim to improve high-level thinking skills (critical, creative, and problem-solving) and students' scientific communication skills [4-11].

The activity laboratory of thermal radiation at the school level is still relatively rare. Most of the heat radiation experiments are to meet research needs such as determining the emissivity value of a material



[12, 13], the effects of heat radiation [14, 15] or the scientific modeling form of the radiation heat process [16].

This study aims to develop activity laboratory at school form of thermal radiation using simple equipment. The expected benefit of the results of this study is to overcome the limitations of teachers to carry out laboratory activities related to thermal radiation due to equipment limitations and highly dependent on the intensity of unstable solar heat.

2. Theoretical

Heat is one form of energy that meets the law of conservation of energy. The law of conservation of energy states that energy cannot be created and destroyed, energy can only be transferred from one form to another. The legal form of conservation of energy in heat energy is indicated in the heat transfer process [17]. The process of energy radiation is transferred emissions from an object of the form of electromagnetic waves. Microscopically, heat radiation is the result of random movement towards atoms in a material so that the movement produces an emission of radiation. The mathematical equations for the radiation of heat of the vacuum chamber are shown:

$$Q = e\sigma T^4 \quad (1)$$

The mathematical equations for radiation heat transfer of two objects or systems are shown

$$Q = e\sigma (T_a^4 - T_b^4) \quad (2)$$

with Q being the amount of heat absorbed or emitted, e is the emissivity of the material, is the Stefan Boltzmann constant which has a value of $5.67 \times 10^{-8} \text{ J / s. m}^2 \text{ K}^4$ and T is the temperature in absolute temperature (Kelvin scale) The equation indicates that the heat energy emitted by the radiation source and can be collected by a heat recovery to be further utilized [18].

The variables that influence radiation heats to transfer process are cross-sectional area (A) and the material characteristics that serve as a reservoir of heat. The cross-sectional area is correlated with the amount of heat received. The larger the cross-sectional area of an object then the object will absorb more heat [19]. Mathematically this correlation yields a new equation that is:

$$Q = e\sigma AT^4 \quad (3)$$

The energy conversion found in life has a lot of variation. For example is the conversion to electrical energy into heat energy. The mathematical equation which states the electrical energy as the amount of electrical power that is passed every time unit:

$$E = Pt \quad (4)$$

where E is energy with unit Joule, P is power with unit Watt and t is time with second unit. The E equation in electric energy has the equilibrium with Q on the heat energy so that by substituting the two equations we get a new equation by:

$$P = \frac{e\sigma AT}{t} \quad (5)$$

3. Experimental method

This research was conducted in physics education laboratory of UIN Sunan Gunung Djati Bandung and SMA Al-Ma'Soem Cileunyi. The first stage in this research started with making thermal radiation equipment. The set of equipment used in the experiment is as follows:

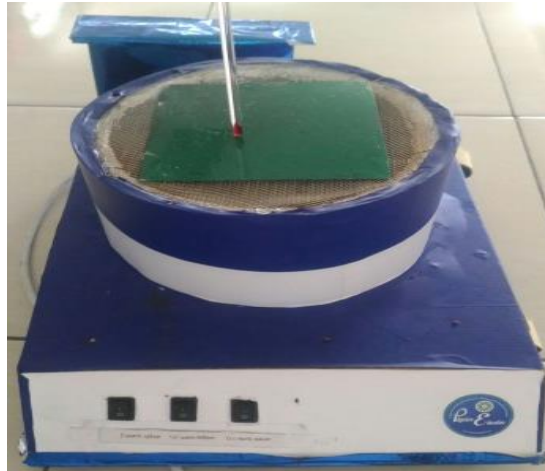


Figure 1. Equipment of laboratory SNR V-1.4SL.

Heating is an element that can convert electrical energy into heat. Heating elements is made with power variations on 0.5; 1.0 and 1.5 milliwatts. Power variations can be used to observe the effect of the heat source on heat received by the test plate. In addition, power variations can also be used as a measure of the efficiency of equipment used. The second equipment is a test plate with a square shape.

The test plate is used as a heat reservoir of a cross-sectional area (A) to determine the effect of the cross-sectional area on the amount of heat received. The size of the black test plate cross section is varied (81; 121; 169) cm^2 . The test plate is made by using aluminum material which has a high conductivity value so that the resulting temperature changes become more easily observed. This selection of aluminum is also based on as a material that has a high melting point so it is not flammable or melts due to the heat received.

The experiment to observe the effect of the cross-sectional area of the absorbed heat is carried out using a test plate made of the same material, color and thickness. The test plate used is then varied from four color variations (white, blue, green, and black) with dimension area 169 cm^2 to distinguish the heat absorption power based on the emissivity coefficient.

The activity laboratory to determine the effect of color on heat absorption is done by using plates made of uniform materials and having the same size and thickness. The last experiment conducted on this laboratory activity is the effect of heating time for the amount of heat absorbed. The data onto the effect of heating time is obtained by varying the heating time for the same plate. The overall measurable independent variables of this apparatus are the cross-sectional area of the test plate, the color of the test plate (emissivity) and the heating time. The measured bound variable of this equipment of laboratory is the surface temperature of the test plate.

The experimental data obtained from the equipment must be processed by the students. The measurement data processing is then substituted for the equation to determine the function of temperature against each independent variable. The form of the function of the equation is as follows

$$T(P) = f(P) \frac{t}{e\sigma A} \quad (6)$$

$$T(e) = \frac{Pt}{\sigma A} \frac{1}{f(e)} \quad (7)$$

$$T(A) = \frac{Pt}{e\sigma} \frac{1}{f(A)} \quad (8)$$

$$T(t) = \frac{P}{e\sigma A} f(t) \quad (9)$$

The final calculation of the design of this experiment is to determine the amount of heat absorbed and determine the efficiency of the equipment created. Calculation of the amount of heat using equation 3 of the experimental data already obtained. Furthermore, the determination of efficiency is done by comparing the calorific value absorbed by the heat released by the heating element [20].

$$\eta = \frac{Q_{\text{serap}}}{Q_{\text{emisi}}} \Delta T \quad (10)$$

4. Result and discussion

The results of testing the equipment radiation thermal showed good results. Trials conducted by students in school and university showed that the thermal radiation laboratory tool be made to meet the concept of radiation heat transfer.

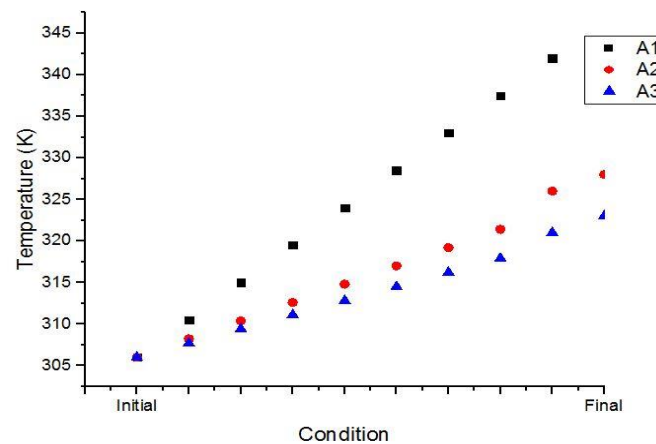


Figure 2. Changes in temperature (T) to the cross section (A).

Based on the data onto figure 2 it is seen that the slope of the graph decreases from increasing size, where $A1 < A2 < A3$ [21]. The slope of the curve indicates a change in temperature.

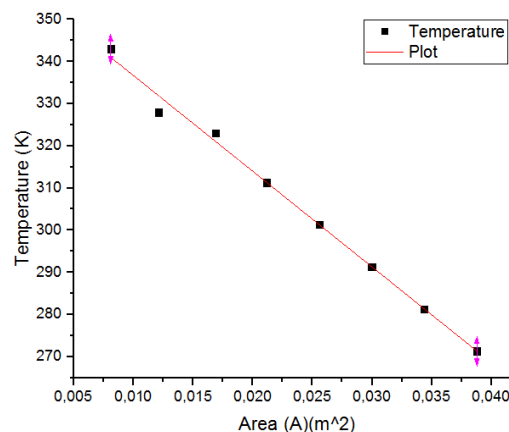


Figure 3. Curve of sectional area of temperature.

Based on figure 3 it is seen that the slope of the graph is negative so that the relationship shown by the cross-sectional area of the temperature is inversely proportional. The result of fitting made to the results shows that the relationship that appears has a second order or parabolic.

The larger cross-sectional area allows the object to absorb more heat. Analytically the test plate with the largest cross-sectional area will absorb the most heat. This is slightly different from the wide relationship to the conduction process. Larger sizes cause the system to require more heat to be able to raise the area temperature of the cross section. This causes the large cross-sectional area to have a low temperature. In general, the increase in cross-sectional area is not part of the radiation heat absorption analysis. Factors that cause temperature raises in the cross-sectional area are a significant conduction factor related to the conductivity value of the material. Temperature cross-section at this laboratory activity becomes indicator of heat absorption by test plate.

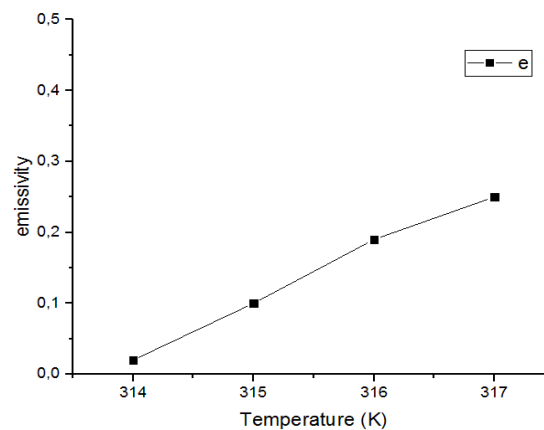


Figure 4. Temperature to emissivity coefficient.

Another factor the affected of thermal radiation is matter character in this study is coefficient of emissivity. The result of test is shown that coefficient of emissivity of the experiment tool still less. For the white flat is having value of coefficient emissivity 0.02, the blue flat 0.1, the green flat 0.19 and the black flat 0.25. The value of coefficient emissivity is less is caused of matter composer. The matter is use to make color of the flat is paint that not homogeneous with the flat.

The curve of coefficient emissivity toward the temperature is shown that the temperature increases with the increase of the value of coefficient of emissivity [22]. The value of slope of curve is positive that indicate the correlation is comparable. Fitting of curve is shown the linear program. Theoritically, the value of coefficient of emissivity has support to heat absorb of the reservoir.

The graph of the correlation coefficient of emissivity to the absorbed heat is shown in figure 5. The graph gives the form of correlation between the emissivity coefficients to the amount of heat absorbed by the object. The greater the value of the object's emissivity coefficient, the more heat absorbed by the object and the measured temperature value of the thermometer will be greater [23]. This reason causes the correlation between the emissivity constant and the temperature rise to be equal and linear.

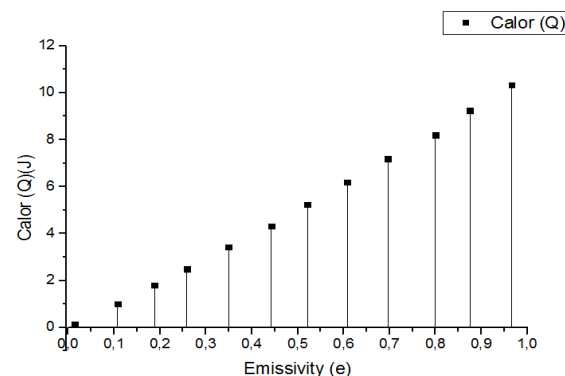


Figure 5. Emissivity constants to heat absorbed.

The last step of this research is calculating the efficiency of the tool. Result of calculating using equation (9) is shown the efficiency of the tool still less. The problem of the tool is how to keep the power that use in the heater. This problem has causing the student fail for they analyse when making a report of experiment.

5. Conclusion

We have been successful in make to heat radiation equipment in an effort to overcome the limitations of laboratory equipment in schools. The result of test thermal radiation equipment SNR V-1.4SL shows can be used to explain the topic of radiation heat transfer precisely. Excess thermal radiation equipment SNR V-1.4SL is easy to use and student easy to measure of each variable. Another benefit the tool may be use every time and everywhere because is not need to the light sun. The deficiency of thermal radiation equipment SNR V-1.4SL is limitations to make of varying the test plate. Difficulty in controlling and stabilizing power becomes the thing that needs to be optimized from this equipment.

References

- [1] C Schiller 2014 *Motion mountain: The adventure of physics (fall, flow and heat)* **1** (Munich: Creative Commons)
- [2] T L Bergman, A S Lavine, F P Incropera and D P DeWitt 2012 *Fundamentals of heat and mass transfer* (New York: Jhon Wiley & Son)
- [3] D Halliday, R Resnick and J Walker 2014 *Fundamental of physics 10th* (New York: Jhon Willey & Son)
- [4] A Malik, A Setiawan, A Suhandi, A Permanasari and S Sulasman 2018 Hot lab based practicum guide for pre-service physics *IOP Conf. Ser.: Mater. Sci. Eng.* 288 012027
- [5] A Malik, A Setiawan, A Suhandi, A Permanasari, A Samsudin, D Safitri, S A S Lisdiani, S Sapriadi and N Hermita 2018 Using hot lab to increase pre-service physics teacher's critical thinking skills related to the topic of RLC circuit *J. Phys.: Conf. Ser.* 1013 012023
- [6] A Setiawan, A Malik, A Suhandi and A Permanasari 2018 Effect of higher order thinking laboratory on the improvement of critical and creative thinking skills *IOP Conf. Ser.: Mater. Sci. Eng.* 306 012008
- [7] A Malik, A Setiawan and A Suhandi 2017 A Permanasari, Learning experience on transformer using hot lab for pre-service physics teacher's *J. Phys.: Conf. Ser.* 895, 012140
- [8] A Malik, A Setiawan, A Suhandi and A Permanasari 2017 Enhancing pre-service physics teachers' creative thinking skills through hot lab design *AIP Conf. Proc.* 1868, 070001
- [9] A Malik and A Setiawan 2016 The development of higher order thinking laboratory to improve transferable skills of students *Procedings 2015 International Conference on Innovation in Engineering and Vocational Education, Atlantis Press* 56, 36–40
- [10] A Malik, A Setiawan, A Suhandi, A Permanasari, Y Dirgantara, H Yuniarti, S Sapriadi and N Heminta Enhancing communication skills of pre-service physics teacher through hot lab

- related to electric circuit *J. Phys.: Conf. Ser.* 953, 012017
- [11] S Sapriadi, A Setiawan, A Suhandi, A Malik, D Safitri, S A S Lisdiani and N Hermita Optimizing students' scientific communication skills through higher order thinking virtual laboratory (HOTVL) *J. Phys.: Conf. Ser.* 1013, 012050
 - [12] T Schmugge, A French, J C Ritchie and A Rango 2002 H Pelgrum, Temperature and emissivity separation from multispectral thermal infrared observations *Remote Sensing of Environment* 79 189-198
 - [13] D B Nestor, A E Shapley, K A Kornei, C C Steidel and B Sianan 2013 A refined estimate of the ionizing emissivity from galaxies at $z = 3$ spectroscopic follow-up in the SSA22a field *The Astrophysical Journal* **765**(40) 1-30
 - [14] M Sheikholeslami, D D Ganji, M Y Javed and R Ellahi 2015 Effect of thermal radiation on magnetohydrodynamic nanofluid flow and heat transfer by means of two phase model *Journal of Magnetism and Magnetic Material* 374 36-43
 - [15] A A Bhuiyan and J Naser 2015 Numerical modelling of oxy fuel combustion, the effect of radiative and convective heat transfer and burnout *The Science and Technology of Fuel and Energy* **139**, 268-284
 - [16] E Ebrahimi Bajestan, M C Moghadam, H Niazmand, W Daungthongsuk and S Wongwise 2016 Experimental and numerical investigation of nanofluid heat transfer characteristic for application in solar heat exchangers *International Journal of Heat and Mass Transfer* **92** 1041-1052
 - [17] J H Lienhard 2017 *A heat transfer textbook 4th* (Cambridge, Massachusetts: Phlogiston Press)
 - [18] A Mojiri 2013 Spectral beam splitting for efficient conversion of solar energy-a review, *Renewable and Sustainable Energy Reviews* **28** 654-663
 - [19] R A Serwey and J W Jewett 2004 *Physics for scientists and engineers 6th ed.* (Thomson Brooks/Cole)
 - [20] T H Anjali and G Kalivarathan 2015 Analysis of efficiency at a thermal power plant *International Research Journal of Engineering and Technology* **2**(5) 1112-1119
 - [21] K P Vemuri and P R Bandaru 2016 An approach towards a perfect thermal diffuser *Scientific Report* **6** 29649
 - [22] H Wang, D Chen, G Wang, Y Long, J Luo, L Liu and Q Yang 2013 Measurement technology for material emissivity under high temperature dynamic heating condition *Measurement* 13
 - [23] M Fu, M Q Yuan and W G Weng 2015 Modeling of heat and moisture transfer within firefighter protective clothing with the moisture absorption of thermal radiation *International Journal of Thermal Science* 96