The Effect of Surface Color on the Absorption of Solar Radiation

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The Effect of Surface Color on the Absorption of Solar Radiation

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Abstract

This research was conducted to verify the effect of the color of the object's surface on the absorption of solar radiation. The purpose of this study was to determine how the effect of surface color on the absorption of solar radiation. The activity used an acrylic box covered by stickers of various colors, placed under the sun, then measured the heat absorption of the covered liquid using a digital thermometer. The results showed that there was an effect of the color of the object's surface on the absorption of solar radiation which was indicated by the difference in the temperature increase of the covered liquid. The hypothesis can be accepted at the 95% confidence level. The order surface color of objects on the absorption level of solar heat is black, green, red, purple, yellow, pink, blue and white from the highest to the lowest.

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INTRODUCTION

Sunlight is the largest source of energy on earth. If it is brought in through a narrow slit and passed on to a prism, then it will experience dispersion (decomposition) into red, orange, yellow, green, blue and purple colors. Each of these light colors has its own characteristics. Red light has high heat effect and small chemical effect compared to purple light having small heat effect, but it has large chemical effect.

Color can be viewed from two points of view, namely physics and materials science (Nugraha, 2005). When it is viewed in terms of wavelength, red light has a large wavelength or a small frequency. Associated with the quantum theory of light, the amount of energy carried in the form of energy packets is inversely proportional to the wavelength. The larger of the wavelength, the less energy of the light carries. This means that the red light has less energy than the purple light. As it is known, the color of an object is the color emitted by the object, meanwhile, other colors of light coming in will be absorbed. Thus, absorbing color of light bumping on a surface of a colored object causes energy absorption by the object.

Many studies on the effect of color on the solar thermal energy's absorption have been previously carried out. Uemoto et al (2010) said that color changes (plain, white, yellow and brown) affect the heat transfer on the roof. The brown colour has the highest external temperature among of those. Each color of light has a different wavelength, and it has different penetration and absorption capabilities (Rahayu et al., 2011). This opinion is supported by research results Fajar & Rohmah (2019) which show that color affects the increase in water temperature due to radiation. The black color is the most significant one because the nature of the black color is to absorb heat completely.

There are several factors that can affect the rate of radiation heat transfer of an object. The factors affecting the rate of radiation heat transfer are the temperature on the surface of an object that emits and absorbs radiation, the emissivity (absorption) of the surface of the irradiated object, reflection, absorption, transmission, and the view's factor between the emitting and radiated surfaces. Surface condition of objects absorbing and emitting radiation affects the rate of heat transfer in the radiation phenomenon. This can happen because the surface of an object has characteristics that can affect the emissivity (emitting power) of an object (Wahyono & Rochani, 2019).

Dark dominant colors such as black and green have better heat absorption than bright dominant colors (red, blue, yellow, and white). Research conducted Anambyah & Setyowati (2010), states that bright colors will reflect light, while dark colors tend to absorb light. These results are supported by Ilminnafik et al (2015) in their research stating dark colors (red) tend to absorb more heat than lighter colors (gray). Also being emphasized by Hardiyanto et al (2016), his research shows that solar radiation is the largest contributor to the amount of heat that enters the building. Research conducted Nazaruddin et al (2020) concluded that the tin roof that absorbs the highest sun's heat is the black tin roof. Meanwhile, the white tin roof is the tin roof with the lowest absorption of solar radiation. If we sorted them based on the ability to absorb solar heat from the highest to the lowest, the color order of the zinc roof is black, red, blue, yellow, and white.

METHODS

The tools and materials applied in this study were acrylic boxes covered with stickers of various colors, digital thermometers, stopwatches, and plastic cups. The acrylic box measures 11 cm x 11 cm x 17 cm, with a thickness of 2 mm. The variables in this study are the color of the object's surface and the absorption of solar radiation energy. To determine the level of absorption of solar radiation by the colored surface of an object, the temperature rise of the covered liquid was measured. The instrument used to measure the temperature rise of a liquid is a digital thermometer. The series of experimental tools are shown in Figure 1.

Figure 1. Experimental Tool Circuit

All acrylic boxes used in this research had the same size both in terms of material type and material thickness. Those were coated with colored stickers which were assembled in such a way that they produce liquid temperature measurement so that the measurement results are relatively the same. Then, each of the acrylic box was filled with liquid which is poured into a plastic cup with the same volume. The thermometer sensor was inserted into a glass filled with liquid and placed in the middle of the liquid. The goal is the temperature measured focus on the temperature of the liquid, not the temperature of the glass wall.

This research was conducted in a fairly spacious place and was carried out during the day when the sun was in the brightest, i.e. from 11.00 WIB to 14.00 WIB. At the time of reading the thermometer scale, pictures of LCD thermometer were taken with a cellphone camera. This was done to minimize the time difference in recording temperature data.

The number of samples in this study were 15 data. During the experiment, the temperature was recorded every 5 minutes. This study will test the hypothesis regarding the effect of surface color on the absorption of solar radiation energy. The data in this study were processed to determine the relationship between the color of the object's surface and its effect on the absorption of solar radiation. The statistic used for data analysis was 1-way ANOVA.

RESULTS AND DISCUSSION

The color of the surface of an object is an independent variable that will affect the amount of absorption of solar radiation. At the time of the experiment, the average air temperature was 32°C and humidity was 7%. The data was processed only for six colors in the visible light spectrum region. While the two standard colors, white and black, were only used as a comparison. The results of observations of the increase in the temperature of the liquid can be seen in Figure 2.

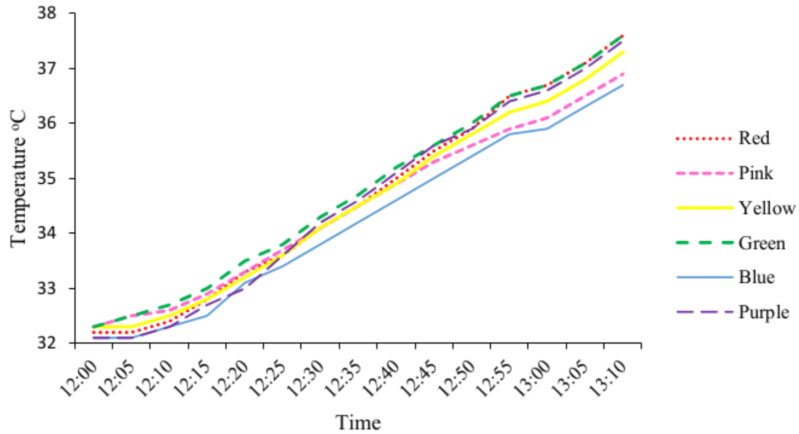

Figure 2. Temperature rise of the liquid enclosed in a colored acrylic box

The measurement results showed that the change in temperature of the liquid enclosed by the black coated acrylic box was an average temperature value of 35,2°C. Of the eight colors observed, it turned out that black showed the highest temperature increase and white showed the lowest temperature increase. Thus, I emphasized that these two colors are for comparison purposes only. From the results of 15 times recording, it was obtained that the average temperature increase of the liquid for the six colors applied in this study was as shown in Figure 3.

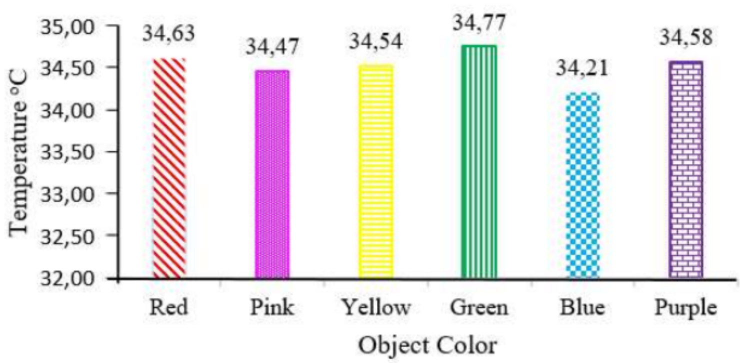

Figure 3. Increase in the average temperature of a liquid

After the obtained data on the increase in temperature of the liquid of each color, data analysis was carried out with one-way ANOVA statistics. From the measurement results, the average value of the largest temperature increase is green at 34,77°C. While the smallest average value is blue with an average temperature of 34,21°C.

Based on the results of the calculation of the number of squares, degrees of freedom, and the average square of each color, the value of F can be calculated. The results of data analysis using one-way ANOVA statistics are shown in Table 1.

Table 1. Data Analysis Results

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Red	15	518.9	34,59333	3.583524
Pink	15	517.1	34,47333	2.394952
Yellow	15	518.1	34.54	2,964
Green	15	521.7	34.77	3.086
Blue	15	513.2	34.21333	2,548381
Purple	15	518.7	34.58	3.533143

ANOVA

				F count		F table
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2,589	5	0.5178	0.171552	0.972458	2.323126
Within Groups	253.54	84	3.018333			
Total	256,129	89				

As we know, with one-way ANOVA, the differences tested are only for data with the largest and smallest average values. When compared to the F value obtained from the calculation results with the F price contained in the table, the calculated F value is greater than the F price in the table for a 95% confidence level. This means that the working hypothesis having been formulated which reads: there is an effect of the color of the surface of the object on the absorption of solar radiation (as indicated by the difference in the temperature increase of the liquid that surrounds it), can be accepted at the 95% confidence level. Thus, different surface colors will absorb solar radiation energy in different amounts.

Based on the description of the research results above, it can be stated that the surface color of objects can absorb different solar heat radiation. Different colors will affect the absorption of different light and heat intensities (Ilminnafik et al., 2015). Light colors will have lower absorption, while dark colors will have higher absorption. This is influenced by differences in light in the form of electromagnetic waves that are absorbed and reflected by each color (Azis et al., 2019). Each color of light has a different wavelength, and has different penetration and absorption capabilities (Rahayu et al., 2011). The order of colors based on the ability to absorb solar heat from the highest to the lowest is black, green, red, purple, yellow, pink, blue, and white. The black surface has good heat absorption. This is because it has an extreme temperature change and it can absorb most of the heat in a short time. Similarly, it can also release most of the heat in a short time. Emissivity shows the ratio of the energy emitted by a particular material by an ideal black body at the same temperature (Jin& Liang, 2006).

CONCLUSION

Based on the results of the analysis, it can be concluded that the working hypothesis stating: There is an effect of the color of the surface of the object on the absorption of solar radiation indicated by the increase on the temperature of the covered liquid, can be accepted at the 95% confidence level. Changes on temperature of liquid and air are caused by differences in the absorption of solar radiation by these colored surfaces. If sorted by the ability to absorb solar heat from the highest to the lowest, they are black, green, red, purple, yellow, pink, blue, and white. The black surface has a great heat absorption capacity. This is because black has an extreme temperature change so it can absorb most of the heat in a short time.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6