A Simple Digital Calorimeter as Practicum Innovation Based on W1209 Thermostat Module

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Abstract. A calorimeter is an instrument used to measure the amount of heat transferred to or from an object. The calorimeter used in schools is analog. The data obtained is less accurate, and students have difficulty interpreting the data. This research aims to create a simple digital calorimeter practicum tool based on the W1209 thermostat module as a practicum medium in schools. This tool was made from cheap materials, and the results are very effective and more precise than analog calorimeters in the laboratory. The test results show that the specific heat obtained is 0.93 kcal/kg°C, and the standard error is 0.03, while the analog calorimeter results are 0.92 kcal/kg°C with a standard error of 0.04. Thus, the tools made have met the standard of eligibility for calorimeters in general.

Keywords: Calorimeter · Digital Calorimeter · Thermostat Module · Specific Heat

1 Introduction

Physics is one of the used sciences for human life applied in technology [1]. Physics is implied in sophisticated equipment that makes all human work more accessible. Instrumentation electronics is one of the fields of physics study that has rapid development [2]. New theories develop through experiments conducted during practicum. Physics practicum aims to discover and inform existing scientific facts [3].

By utilizing practicum techniques, active learning can be accomplished. The practicum method is a learning method carried out through an experiment [4]. However, experiments in the laboratory generally still use analog measuring instruments [5]. Analog measuring instruments cause the data obtained to be inaccurate, so students have difficulty interpreting the data. Among the factors that cause inaccurate data are tool calibration, scale reading, and accuracy of tool use [6]. One practicum that still uses analog measuring instruments in schools and universities is the calorimeter.

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A calorimeter is used to measure the amount of heat released or received by an object. One of the critical uses of the calorimeter is in determining the specific heat of certain substances [7]. Previous relevant research is making electronic calorimeters based on Arduino microcontrollers [8, 9]. But the calorimeter developed is still very complex and less practical. In addition, other researchers have made simple calorimetric teaching aids from used cans that are environmentally friendly and safe to use [10, 11, 12]. But the tool is still analog. Therefore, the innovation of making practical, effective, and inexpensive digital calorimeter practicum tools is significant to increase the practicum's effectiveness and achieve more precise results.

2 Method

This research was conducted in May 2022 at the Physics Laboratory, Faculty of Mathematics and Natural Sciences, University of Mataram. The method used is the experimental method [13], making a digital calorimeter from used materials, testing the tool, and comparing it with an analog calorimeter. The tools used in this research are PVC pipe, Styrofoam, W1209 digital thermostat module, temperature sensor, battery, and stirring rod. Testing tools using hot water and cold water.

The process of making a simple digital calorimeter: cutting PVC pipe and cutting the styrofoam into small, rounded rectangles; the rectangular styrofoam is glued and affixed to the inner pipe while the round styrofoam is placed on the bottom cover of the tube, the top pipe cover is drilled to form a hole, connect the positive and negative poles of the battery with the button and then also connect to the digital thermostat module, attach the thermostat module to the top of the can cover with screws, and then insert the sensor through the drilled hole (Fig. 1).

The process of testing a simple digital calorimeter: calibration of digital devices with analog thermometers, which equalizes the temperature read on the thermometer with the temperature read on the thermostat sensor, weighing the mass of cold water, considering the digital calorimeter, putting cold water into the calorimeter and measure the initial temperature, then heat the water and measure the temperature of the hot water, weigh the mass of hot water, add cold water to the hot water and mix it, measure the temperature after mixing, and do the same experiment up to three times (Fig. 2).

Fig. 1. The process of making a simple digital calorimeter

Fig. 2. The process of testing a simple digital calorimeter

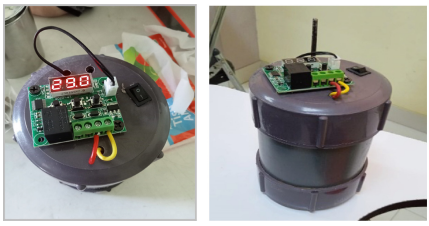

Fig. 3. The design of a simple digital calorimeter

3 Results and Discussion

3.1 The Result of the Design of a Simple Digital Calorimeter

The calorimeter tool that has been designed is a simple calorimeter made from used materials, namely PVC pipe, styrofoam, and aluminum glass. As for what distinguishes it from calorimeters in general, this calorimeter uses a sensor to measure temperature digitally. The sensor is excellent for avoiding errors in reading analog tools [14, 15]. In addition, this tool is handy for application at the high school and college levels because it can help students develop science process skills [16], critical thinking skills [17], and mastery of concepts [18], which learn about temperature and heat (Fig. 3).

3.2 The Result of Testing a Simple Digital Calorimeter

One type of energy released or received by objects is heat [19, 20]. This experiment used a mixture of two ingredients with different temperatures. Cold water with a temperature of T1 mixed with hot water has a temperature of T2 in the calorimeter. In the tool, there is a process of releasing heat with hot water and receiving heat with cold water. The condition when the mixing process occurs is adiabatic so that the heat in the system does not go out into the environment [21]. Therefore, the calorimeter has been designed to use styrofoam as an insulator between the aluminum glass and the pipe.

Previously the tool was calibrated first. The temperature sensor is calibrated with a standard tool, namely an analog thermometer [22]. The test results are then compared with the analog calorimeter results. The following are the results of the digital calorimeter test, and the calculation results can be seen in Table 1 and Table 2.

Based on the Table 2, the average specific water heat from the three repetitions was 0.93 kcal/kg°C with a standard error of 0.03. This result is close to the theoretical specific

Table 1. The result of testing a simple digital calorimeter

Test	Calorimeter		Hot water		Cold water		Mix Temp. Tm (°C)
	mcal (kg)	Tcal (°C)	m1 (kg)	T1 (°C)	m2 (kg)	T2 (°C)	
1	0,31	31,30	0,07	81,80	0,07	31,30	56,90
2	0,31	31,30	0,06	61,30	0,07	33,60	46,70
3	0,31	31,30	0,11	82,40	0,09	31,90	59,00

Table 2. The result of heat capacity and specific heat of water with a simple digital calorimeter

Test	Q = m c ΔT (kkal)		Heat capacity and specific heat of water	
	m1 c (T1-Tm)	m2 c (Tm-T2)	C (kcal/°C)	c (kcal/kg°C)
1	1,82	–1,87	0,14	0,99
2	0,89	–0,89	0,12	0,90
3	2,55	–2,63	0,19	0,91
Average			0,15	0,93
Standard deviation			0,04	0,05
Standard error			0,02	0,03

heat of water, which is 1 kcal/kg°C [23]. So, it can be said that the digital calorimeter that has been made can already be implemented in the learning process on temperature and heat material.

Furthermore, these results are compared with experimental results using an analog calorimeter. The following experimental and calculation results can be seen in Table 3 and Table 4.

Based on the data above, the results obtained are the average specific heat of water is 0.92 kcal/kg°C with a standard error of 0.04. Similar to the results of a digital calorimeter, the calculation is close to theory. However, a digital calorimeter is more precise because the standard error is smaller than an analog calorimeter. Thus, the tools that have been made already meet the standard of eligibility for calorimeters in general.

Table 3. The result of testing an analog calorimeter

Test	Calorimeter		Hot water		Cold water		Mix Temp. Tm (°C)
	mcal (kg)	Tcal (°C)	m1 (kg)	T1 (°C)	m2 (kg)	T2 (°C)	
1	0,11	30,00	0,05	69,00	0,05	30,00	50,00
2	0,11	30,00	0,08	82,00	0,07	29,00	59,00
3	0,11	30,00	0,10	83,00	0,09	29,00	58,00

Table 4. The result of heat capacity and specific heat of water with an analog calorimeter

Test	Q = m c ΔT (kkal)		Heat capacity and specific heat of water	
	m1 c (T1-Tm)	m2 c (Tm-T2)	C (kcal/°C)	c (kcal/kg°C)
1	0,95	–1,04	0,10	0,99
2	1,91	–2,06	0,13	0,87
3	2,60	–2,72	0,18	0,92
Average			0,14	0,92
Standard deviation			0,15	0,06
Standard error			0,16	0,04

4 Conclusion

Based on the research objectives, the conclusion is a simple digital calorimeter made using PVC pipe, styrofoam, aluminum glass, and a thermostat sensor. The result of measuring the specific heat of water using a simple digital calorimeter is 0.93 kcal/kg°C with a standard error of 0.03, while the specific heat of water using an analog calorimeter is 0.92 kcal/kg°C with a standard error of 0.04. Thus, the tools that have been made already meet the standard of eligibility for calorimeters in general.

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