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DESIGN AND PERFORMANCE EVALUATION OF ALCOHOL THERMOMETER WITH A GLOW IN THE DARK FEATURE FOR TEMPERATURE MEASUREMENT

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ABSTRACT

Developing temperature-measuring instruments from simple materials is essential to supporting physics education, particularly by linking thermal expansion in liquids to engaging, easily observable visual innovations. This study describes the design and evaluates the performance of a simple, alcohol-based thermometer with a "glow in the dark" property, intended as a demonstration tool for temperature changes. The prototype consists of a glass bottle (reservoir), a transparent straw (observation column), modeling clay (to seal the connection), and a ruler (to measure changes in liquid height). We added luminescent powder to provide a visual effect in dark conditions. Observations indicate that the liquid column length increased from 13 mm at 0 °C to 23 mm at 5 °C, yielding a two-point gradient of 2 mm/°C. Qualitative testing showed the liquid column rising and falling during heating and cooling, and the "glow in the dark" feature produced a greenish luminescence. However, due to limited data and a lack of calibration, the study could not determine the device's accuracy, precision, or linearity. The study concludes that while the prototype has potential as a physics demonstration tool, further testing, including standardized calibration and repeated observations across various temperature conditions, is required to ensure the reliability of its quantitative temperature measurements.

1. INTRODUCTION

Temperature measurement is crucial to physics education and experimentation because it provides information about a system's thermal state (Finegan et al., 2021). Temperature is a physical quantity that describes an object's degree of hotness or coldness (Nakkir & Efendi, 2023). Understanding temperature is essential for explaining various natural phenomena, particularly those related to heat transfer and temperature-induced changes in material properties. Consequently, temperature-measuring instruments play a vital role in supporting both educational activities and experimental observations. A thermometer measures temperature based on changes in a material's physical properties resulting from temperature fluctuations (Prihandono, 2021; Rachmat & Ananda, 2024). Its measurement principle relies on material characteristics that respond to changes in thermal conditions. One common type is the liquid-in-glass thermometer, which operates based on

the principles of thermal expansion and contraction of a liquid. These volume changes manifest as the movement of the liquid's surface within a narrow channel, allowing observation and correlation with temperature changes.

The principle of liquid expansion underpins the relationship between temperature and a material's volume (White et al., 2022). When a liquid absorbs heat and its temperature rises, its volume typically increases, raising the liquid level in the observation channel. Conversely, a decrease in temperature reduces volume, lowering the height of the liquid column (Tona, 2022). This phenomenon illustrates the connection between temperature changes and the liquid's physical response as the measurement medium. In physics education, a simple thermometer helps students grasp concepts such as temperature, heat, and thermal expansion more concretely. Direct observation of changes in the liquid level helps students link theoretical explanations to the phenomena occurring during an experiment. Furthermore, designing and constructing a thermometer provides practical experience with the operating principles of such instruments, material selection, and the factors that influence temperature-measurement results.

Temperature measurement uses a scale system to quantify temperature values. Common scales studied in physics include Celsius, Réaumur, and Fahrenheit (Prihandono, 2021). These scales differ in how they define fixed points and divide measurement intervals. Under standard atmospheric pressure, the melting point of ice and the boiling point of water serve as benchmarks for establishing thermometer scales. Understanding these scale systems is fundamental to calibration and interpreting temperature measurements. Developing simple thermometers is an effective way to introduce the principles of physical instrumentation using easily accessible materials (Utami & Jhoni, 2022). Using a glass bottle as a reservoir, a clear straw as a conduit, modeling clay (plasticine) as a sealant, and a ruler as an indicator, you can build a device that demonstrates temperature changes. While this design may not meet the rigorous standards of professional measuring instruments, it effectively illustrates how a liquid column's height responds to temperature changes.

One approach to developing a simple thermometer is to use alcohol, which changes volume in response to temperature fluctuations (Puspawarna et al., 2026). Alcohol is chosen for its thermal expansion properties, which allow observers to see changes in the liquid column height through a transparent conduit (Music & Stancic, 2023). This design also allows examination of how temperature shifts affect the liquid surface position (Puspawarna et al., 2026). However, observation precision depends on factors such as conduit dimensions, reservoir condition, seal stability, and accurate scale placement. This study's innovation adds a "glow in the dark" feature to an alcohol-based thermometer. The laboratory report describes this as adding a powder referred to as "phosphor" to the alcohol, creating a luminescent effect in the dark (Liao et al., 2022). This development resulted in a prototype called the "Glow in the Dark Thermometer." The luminescent feature is intended to add a visual characteristic that enhances the device's appeal as a tool for demonstrating physics concepts, without altering the fundamental principles underlying the observation of liquid expansion (Zhang et al., 2023).

Although it has distinct visual characteristics, developing an alcohol-based thermometer with a "glow in the dark" feature still requires evaluating its performance and limitations. Key aspects to consider include the device's ability to reflect changes in the liquid level, the alignment of the alcohol column's movement with temperature fluctuations, and the readability of the observation scale. Furthermore, carefully assess the inclusion of a luminescent substance, as it may alter the

mixture's properties and affect observation clarity. Consequently, the evaluation of the device should not be limited to its visual appearance, but must also examine whether its thermal response aligns with the underlying physical principles. Accordingly, this article explains the operating principles, describes the design process, and evaluates the performance of a simple alcohol-based thermometer featuring a "glow in the dark" component. The evaluation focuses on the device's construction, the installation of a scale, observations of changes in the alcohol column height in response to temperature variations, and how these observations align with the principles of liquid thermal expansion. The findings are intended to provide insight into the potential and limitations of developing simple thermometers as demonstration instruments for physics education.

2. METHOD

2.1 Tools and Materials

The primary materials include a glass bottle to hold the liquid, alcohol as the thermometric substance, phosphor powder as a luminescent agent, a clear straw to visualize changes in the liquid level, and modeling clay (plasticine) to seal the connection between the straw and the bottle cap. Supporting tools include scissors to make a hole in the cap and cut materials, adhesive to attach a scale, a ruler or measuring scale to record the liquid's position, and containers holding hot water and cold water/ice as testing environments. The source report does not specify the quantity and concentration of the alcohol, the mass of the powder, the straw's dimensions, or the bottle's volume.

2.2 Prototype Construction Procedure

The construction process begins by gathering all necessary components and creating a hole in the bottle cap using scissors. Then, pour alcohol into the glass bottle and mix it with phosphorus powder. Once the container is sealed, insert a clear straw through the hole in the cap to serve as a channel for the liquid surface to move. Modeling clay (plasticine) is applied around the connection point to seal the cap opening tightly. A ruler or measurement scale is attached to the side of the bottle and the straw with adhesive, allowing observation of any shifts in the liquid level. The photographic documentation in the report illustrates the stages of filling the bottle with alcohol, mixing in the powder, attaching the cap and scale, and culminating in the final, fully assembled prototype.

2.3 Testing and Observation

We tested the device by preparing hot water and cold water (or ice) in separate containers. We first exposed the prototype to hot water, then observed and measured the change in the liquid's position within the straw using a scale. The device was then moved to cold water/ice to observe the liquid column's descent. Subsequently, the thermometer was placed in ambient room conditions and then moved to a dark environment to document its phosphorescent (glowing) capability. The report presents two data pairs consisting of temperature and liquid column length: 0°C–13 mm and 5°C–23 mm. The report provides no information on the number of repetitions, immersion duration, hot-water temperature, the reference thermometer used for comparison, or the device's uncertainty.

2.4 Data Analysis

We conducted a descriptive analysis by comparing the direction of change in liquid height during heating and cooling. We calculated the gradient between two available data points using Equation 1. This value represents only the slope between two observation points and is insufficient to establish linearity over a broader temperature range. We explicitly compare this gradient with the values stated in the original report as a note on data consistency.

3. RESULTS AND DISCUSSION

3.1 Design and Construction of a Glow-in-the-Dark Alcohol-Based Thermometer

The design and construction process shows that a simple, alcohol-based thermometer with a "glow in the dark" feature can be built using readily available, easy to assemble components. The prototype consists of a glass bottle as the reservoir, a transparent straw as the observation channel, modeling clay (plasticine) to seal the connections, and a ruler to indicate changes in the liquid column height. Alcohol serves as the thermometric medium, responding to temperature fluctuations, while adding luminescent (glow in the dark) powder provides visibility in low-light conditions. Integrating these components creates a device that combines liquid thermal expansion with visual feedback. As documented during the practical work, we successfully assembled all components into a prototype that demonstrates shifts in the liquid level in response to thermal changes.

From a physical perspective, the thermometer operates based on thermal conditions that affect the liquid volume and the pressure within the system. As temperature rises, the alcohol expands, raising the liquid level in the straw. Conversely, a decrease in temperature contracts the liquid volume, lowering the liquid level. However, in this specific bottle-and-straw configuration, trapped air, internal pressure fluctuations, and seal integrity may also affect the liquid column height. These factors indicate that alcohol thermal expansion alone does not determine the device's response. Consequently, the assembled device must be evaluated for its ability to exhibit a thermal response, while acknowledging its inherent limitations as a temperature-measuring instrument.

3.2 Analysis of the Relationship Between Temperature and Changes in the Height of an Alcohol Column

Observations show a change in the liquid column length under two different temperature conditions. The liquid column length was 13 mm at 0°C, and at 5°C it increased to 23 mm. This 5°C temperature increase was accompanied by a 10 mm increase in liquid column length. These findings show a positive correlation between temperature and the change in the alcohol column height within the observed range. Conceptually, this trend aligns with the operating principle of liquid-in-glass thermometers, which use changes in a substance's physical properties due to temperature variations. Table 1 presents the observational data.

Table 1. Results of observations on the relationship between temperature and the length of the liquid column

No.	Temperature (°C)	Liquid Length (mm)
1	0	13
2	5	23

Based on the data in Table 1, we can analyze the relationship between temperature and liquid column length using a simple gradient calculation. The gradient is determined by the ratio of the change in liquid column length to the change in temperature, as shown in Equation 1. This value indicates that, between two observation points, a 1°C temperature change corresponds to an average increase in liquid column length of 2 mm. Nevertheless, these results are insufficient to conclude that the device has constant sensitivity or a linear relationship over a broader temperature range. A comprehensive determination of the thermal response characteristics requires testing across a wider range of temperatures, with a sufficient number of repeated observations.

$$\frac{\Delta L}{\Delta T} = \frac{(23-13)}{(5-0)} = \frac{10}{5} = 2mm/^{0}c \quad (1)$$

3.3 Evaluation of Thermometer Response to Heating and Cooling

Thermal response testing involved heating a bottle containing an alcohol mixture with hot water. Laboratory documentation indicates that this caused the liquid level within the straw to rise. This phenomenon shows that the prototype can provide a visual response to changes in surrounding thermal conditions. Theoretically, the rise in the liquid level can be attributed to the thermal expansion of the alcohol as its temperature increases. However, changes in air pressure within the reservoir may also influence the observed response. Thus, while the observations confirm that the device exhibits a thermal response, the specific contribution of each physical mechanism to the change in the liquid column height remains undetermined.

We performed cooling tests by placing the prototype in a container of cold water or ice to observe the liquid's movement as the ambient temperature decreased. The documentation shows that the liquid level in the straw dropped as it cooled. This reversal indicates a distinct response to heating versus cooling, consistent with the concepts of thermal expansion and contraction of liquids studied in introductory physics. Nevertheless, the report lacks comprehensive numerical data on temperature changes, response times, and liquid-level stability. Consequently, the findings are limited to qualitative observations, precluding a quantitative analysis of the device's dynamic characteristics.

The response to heating and cooling serves as an initial indicator for evaluating a thermometric device's ability to detect changes in thermal conditions. An effective temperature-measuring instrument should yield consistent readings under the same temperature conditions. For this prototype, the testing did not include an analysis of hysteresis, repeatability, or measurement uncertainty. Hysteresis refers to discrepancies in readings at the same temperature depending on whether the device is heating or cooling. Repeatability indicates the instrument's ability to produce consistent responses across repeated tests. Limited documentation suggests the prototype's

operational characteristics still require further experimental evaluation before it can be used as a quantitative measurement instrument.

3.4 Visual Characteristics of the "Glow in the Dark" Feature

The "glow in the dark" feature is the primary innovation that distinguishes this prototype from conventional alcohol-based thermometers. We developed this feature by adding a powder, referred to in the laboratory report as a "phosphor," to the alcohol, creating a luminescent appearance in dark conditions. Testing documentation reveals a greenish glow emanating from the section of the bottle containing the mixture. These results indicate that adding a luminescent substance produced a visually observable effect. However, the specific chemical composition and the precise mechanism of light emission for the material used have not yet been identified. Consequently, the success of the "glow in the dark" feature in this study is based solely on visual observation, rather than on quantitative measurements of optical characteristics.

Including this luminescent feature could help develop more engaging physics educational tools by integrating thermal concepts with materials' optical properties. The prototype's emitted light can be used to introduce luminescence while also allowing observation of fluid displacement in response to temperature changes. Nevertheless, generating light does not inherently prove that the thermometer scale is more readable in dark conditions. The current laboratory report lacks data on luminescence intensity, light-emission duration, or the added powder's impact on the fluid's flow properties. Therefore, further testing is needed to establish the relationship between the luminescent material's characteristics, visualization quality, and the device's effectiveness in facilitating reading the fluid column height.

3.5 Performance Evaluation, Limitations, and Development Potential

An overall evaluation of the design indicates that the "glow in the dark" alcohol-based thermometer offers advantages in construction simplicity, ease of sourcing materials, and the ability to demonstrate temperature-change phenomena visually. The relatively straightforward assembly makes the device suitable as a demonstration tool for introductory physics education, specifically to illustrate concepts such as temperature, thermal expansion, and the thermal response of materials. Furthermore, the inclusion of a luminescent (glow in the dark) substance adds a visual feature that could enhance the appeal of experimental activities. However, these merits do not mean the prototype has sufficient measurement accuracy and precision. Data limitations, the lack of comparison with a calibrated thermometer, and the potential influence of air trapped in the reservoir suggest the device remains in an early stage of development.

Future development should focus on refining the construction, calibrating the device, and systematically testing its thermal and optical characteristics. Measurements should be taken against a calibrated reference thermometer across a broader temperature range to evaluate linearity, sensitivity, accuracy, and measurement uncertainty. Repeated testing is also essential to assess response repeatability and check for potential hysteresis during heating and cooling cycles. Additionally, the luminescent material requires characterization to assess its light intensity, luminescence duration, and any potential impact on liquid movement. Based on the current results, the prototype successfully changed the alcohol column height from 13 mm at 0 °C to 23 mm at 5

°C, provided a visual response to heating and cooling, and showed a luminescent appearance in the dark. These findings highlight the device's potential as a demonstration tool for physics education; however, its development into a reliable temperature-measuring instrument will require further experimental validation.

4. CONCLUSION

Based on the design and evaluation, we developed a prototype alcohol-based thermometer with a "glow in the dark" property that provides a visual response to temperature changes. The device, constructed from a glass bottle, a transparent straw, modeling clay (plasticine), and a ruler, shows changes in the liquid column height as it heats and cools. Observations indicate that at 0°C, the liquid column reaches 13 mm, while at 5°C it increases to 23 mm, yielding a two-point gradient of 2 mm/°C. Adding a luminescent material produces a greenish glow in the dark, adding a visual feature that could support physics education. Nevertheless, because of a limited dataset, no calibration against a reference thermometer, and a lack of optical characterization, the device's accuracy, precision, and linearity cannot yet be determined. Consequently, this prototype is best suited as a demonstration tool for concepts related to temperature and the thermal expansion of liquids. Future development should focus on refining the construction, testing across a broader temperature range, repeating measurements, and characterizing the luminescent material to improve the device's reliability and its potential as a temperature-measuring instrument.

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