# Olimpiad Fizik Malaysia 2026

## Virtual Experiment (100 pts)
## Variable Area Resistor

Feb 2026
Practice Experiment

**Instructions and Information for Participants:**

1. This paper contains 1 experimental question that will require an electronic device with Internet connection to access, preferably a laptop or computer.
2. Participants are not expected to finish all of the questions. *Answer as many as possible.*
3. All answers and workings must be written on foolscap paper. Any work done on the question paper will not be graded except for printed diagrams where applicable.
4. All data used in calculations must be recorded and tabulated clearly, with units and consistent significant figures.
5. Graph papers used must be labeled clearly. This also includes your name, the question number, and all other details of the graph (eg, axes, units, etc.).
6. All workings should be shown clearly in *black/blue pen or 2B pencil*, as they will be graded in addition to the final answers.
7. Any external assistance, such as communicating with a non-participant, is *strictly prohibited.* Any student caught violating this rule shall be void of their eligibility of placement in the Malaysian national team for IPhO 2026.

*Questions on the Next Page*

# 1 Variable Area Resistor

## 1.1 Introduction

Resistive bridge circuits appear in real-world sensor systems including strain gauges, temperature sensors (RTDs and thermistors), pressure transducers, and precision readout electronics.

In this virtual experiment, we probe the electric potential $V(x)$ along a resistive wire and study how it varies with the position $x$ along the wire. In the ideal case, the potential drop is linear and the bridge balance point provides a robust way to determine an unknown resistance. Here however, we study a system of non-uniform material, finite instrument resolution, and electronic noise which introduce deviations from the normal case.

## 1.2 Experimental Setup

The simulation link can be accessed at the following link:

https://ongzzzzzz.github.io/var-area-res

(that's 6 z's!) You should see a page similar to the below when you enter the correct website.

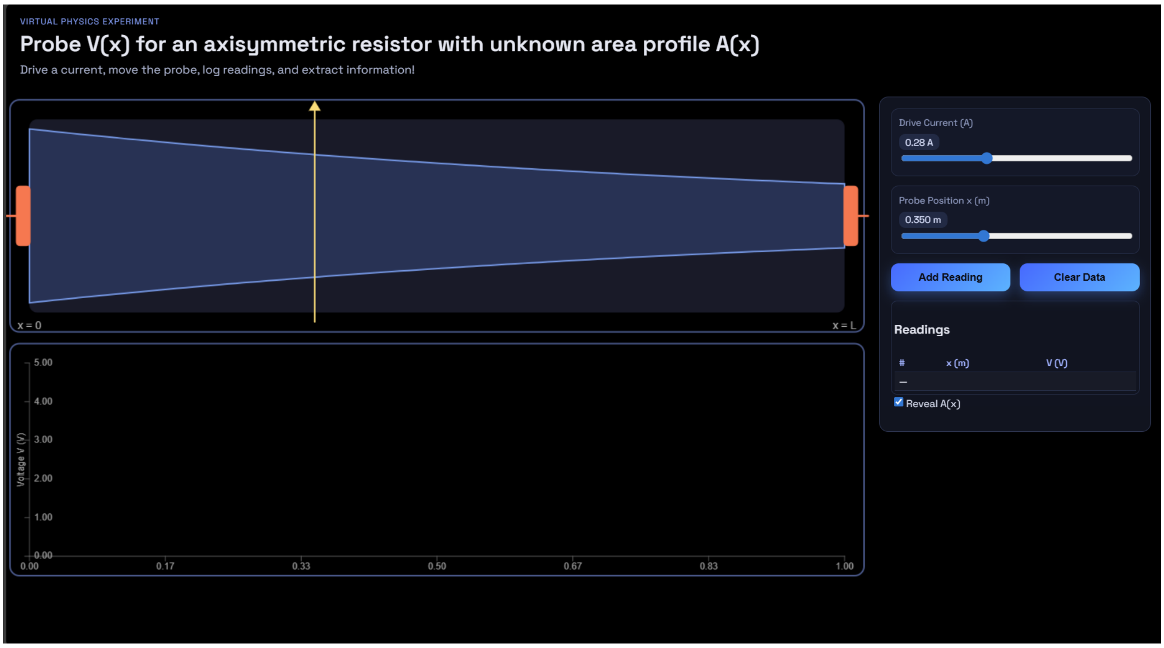
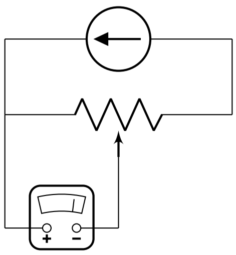



Figure 1: Screenshot of the working webpage.

The setup is an axisymmetric (i.e. symmetric about the central axis) resistor with an unknown area profile $A(x)$. This resistor is hooked up to an ideal current source and a voltmeter, as shown below.



Your task is to figure out parameters of this unknown resistor based on voltage measurements.

## 1.3 Experiment

The resistor has total length $L = 1$ cm and characteristic radius $r_0$. Assume throughout the experiment that $r_0 \ll L$, such that current flows only along the $\hat{x}$ direction.

1. *(5 pts)* What is the total resistance of the whole unknown resistor?
2. *(25 pts)* Record a table of values that you could use to extract information about $r(x)$, the radius profile of the axisymmetric resistor.

There are a few models for the radius profile of the resistor. In particular:

- A tapered radius profile $r(x) = r_0 \exp(-(x/\ell)^2)$
- An exponential radius profile $r(x) = r_0 \exp(-x/\ell)$
- A power law profile $r(x) = r_0(1 - x/\ell)^{-n}$

3. *(20 pts)* Based on your measurements, which one of the profiles above could it possibly be? Make a convincing plot that you can use to extract the relevant parameters $r_0$ and $\ell$.

In all systems around us, there exists noise due to the microscopic fluctuations that is not removable. In electrical systems in particular, due to the random thermal motion of charge carriers, voltages fluctuate ever so slightly - which is measurable in a lab! This is **Johnson noise**, which states that the mean-squared voltage is given by

$$\langle V_{\text{noise}}^2 \rangle = 4 \cdot k_B T \cdot R \cdot B$$

where $B = 9 \cdot 10^9$ Hz is the bandwidth (which you can take to be just another constant in this experiment), $R$ the resistance, $T$ the temperature and $k_B$ the Boltzmann constant.

4. *(30 pts)* Based on the given information, deduce the temperature of the simulation.

The standard error of the sample variance ($s^2$) calculated from a dataset is given as

$$\text{SE}(s^2) \approx s^2 \sqrt{\frac{2}{N-1}}$$

5. *(10 pts)* If you wanted to achieve a 10% uncertainty on the temperature of your simulation, how any samples do you have to take?
6. *(10 pts)* For the mean voltage at one point, how many samples do you have to take to achieve 10% uncertainty? *(Hint: the standard error on the mean is given by $SE(\bar{x}) = \sigma_x/\sqrt{N}$.)*