

# Undergraduate Research on Applications of Thermoelectric Generators

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**INTRODUCTION:** Heat waste harvesting with thermoelectric systems is a clean, environmentally friendly energy producing option among several methods currently considered. The present study investigates the ability of Comsol Multiphysics to develop models that generate data in good agreement with data collected on experimental systems. We developed a three component system (Bismuth Telluride TEG, water cooler and heat sink) and compared the electrical potential generated versus a variety of temperature and water flow values. The agreement between the model and experimental data is extremely good. An experimental set up was also developed for a thermoelectric generator with and without heat sink exposed to the sun light with a Fresnel lens. The data collected will be used in a model that incorporates Fresnel lenses.

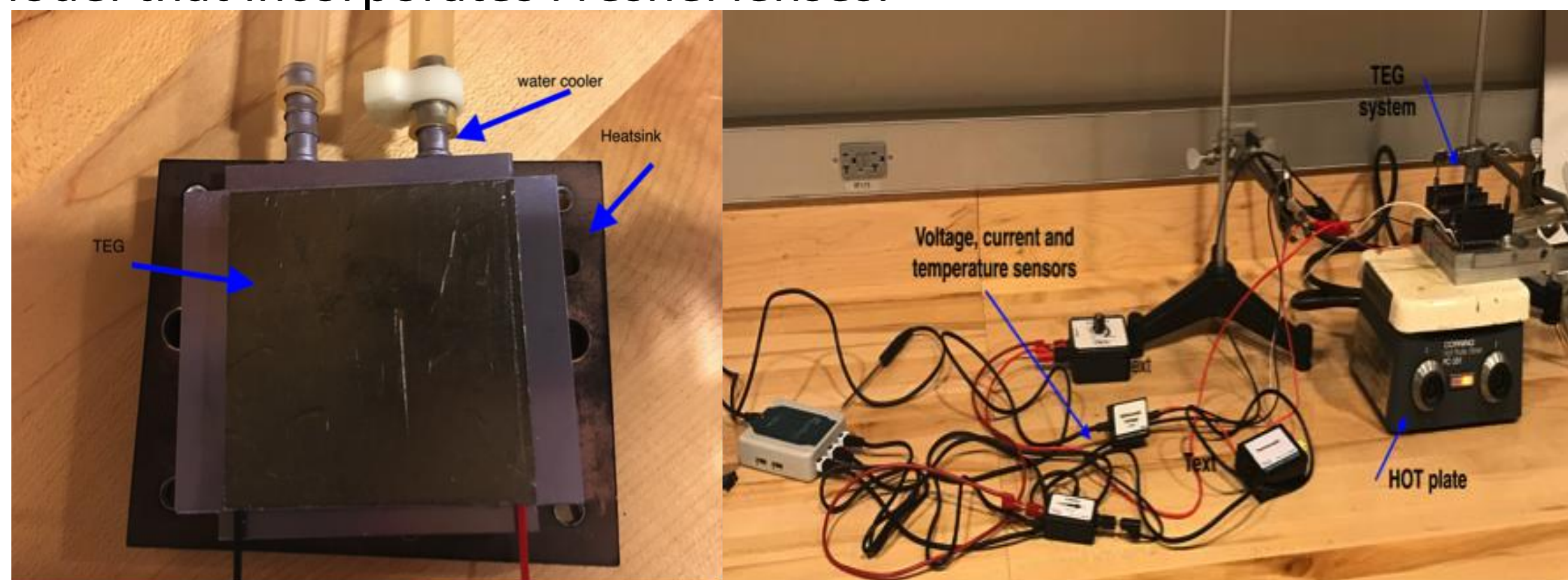


Figure 1. Three component experimental thermoelectric system

## COMPUTATIONAL METHODS:

Comsol Multiphysics solves the double coupling between current and temperature due to Joule heating. The model uses only heat transfer by conduction. Convection and radiation can be included but both have been shown to have a negligible effect on our results. The equations solved are the thermoelectric effect and electromagnetic heating for the thermoelectric material, the electromagnetic heating for electrical contacts and the heat transfer only for the material of the top and bottom faces. For the airbox enclosing the system, the program solves the nonisothermal flow of air by coupling heat transfer (conduction and convection) and laminar (or turbulent) flow and solves for heat transfer by conduction in the heatsink and silica glass plate using the Navier-Stokes equations. For the water flow in the water cooler, the Comsol program solves the Navier-Stokes and continuity equations for the fluid (water) and the heat transfer equations for conduction and convection. The parameters used for the model are the inlet velocity  $v_0$ , the cold and hot temperatures of the bottom surface and top surfaces and the temperature of the in

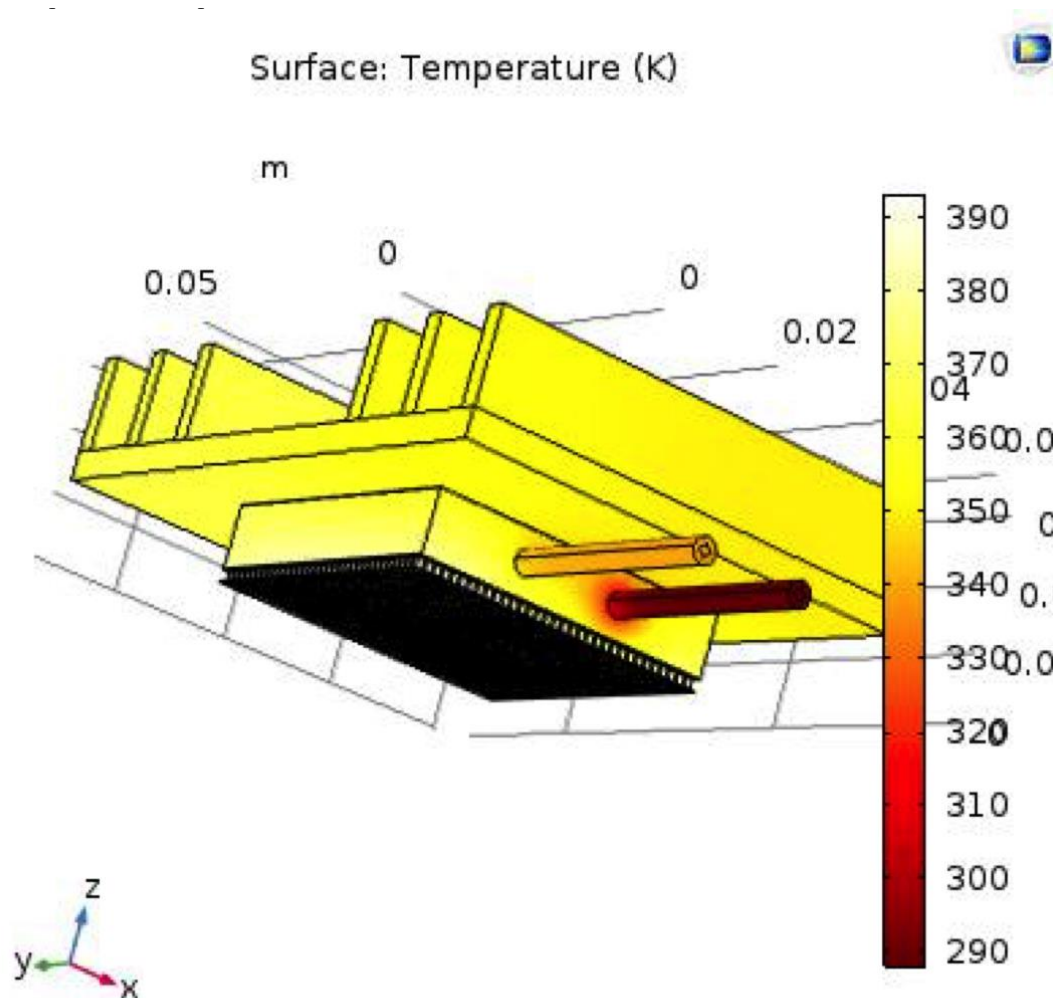


Figure 2. Three component thermoelectric system Comsol Model

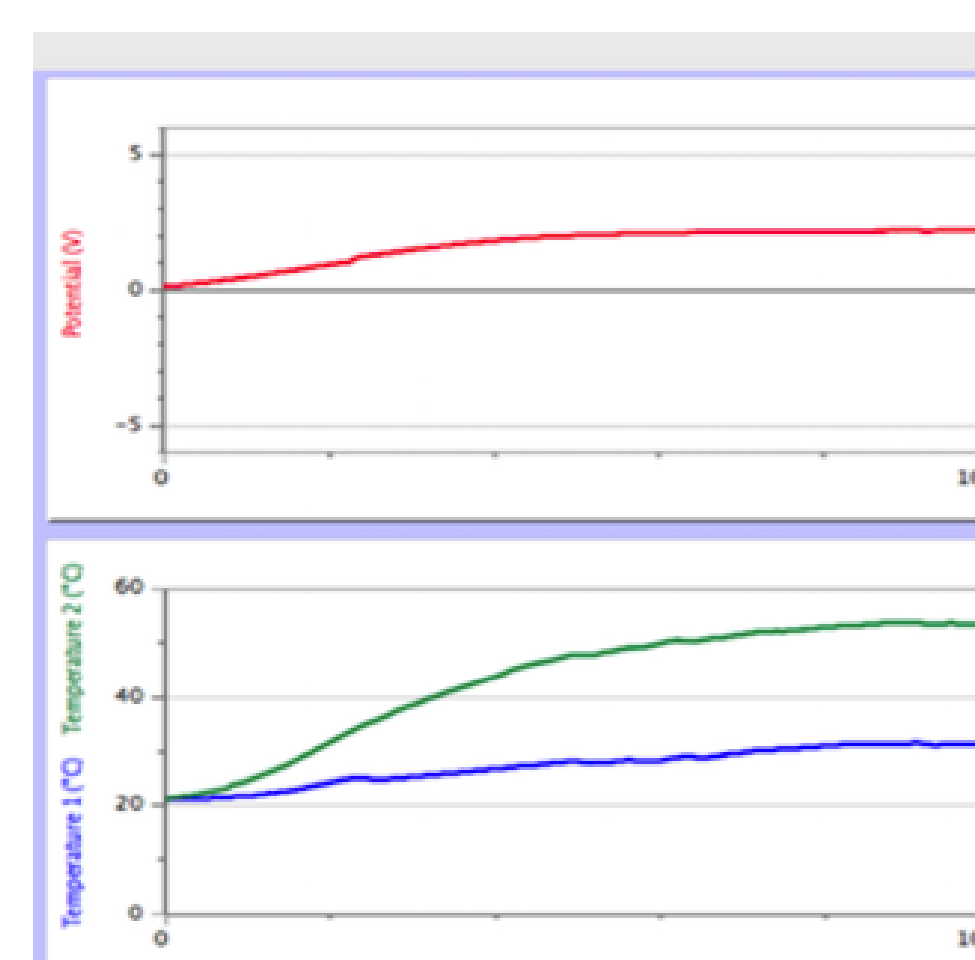


Figure 3. Experimental data collected on the system shown in Fig. 1. The temperature data was used as input for the Comsol model calculations of the electrical voltage versus the temperature difference between the hot and cold plate.

**RESULTS:** The graph in Fig. 4 shows excellent agreement between the experimental and Comsol model data. The electrical voltage generated differs by less than 6.5% from the Comsol calculated values across a wide range of temperature differences.

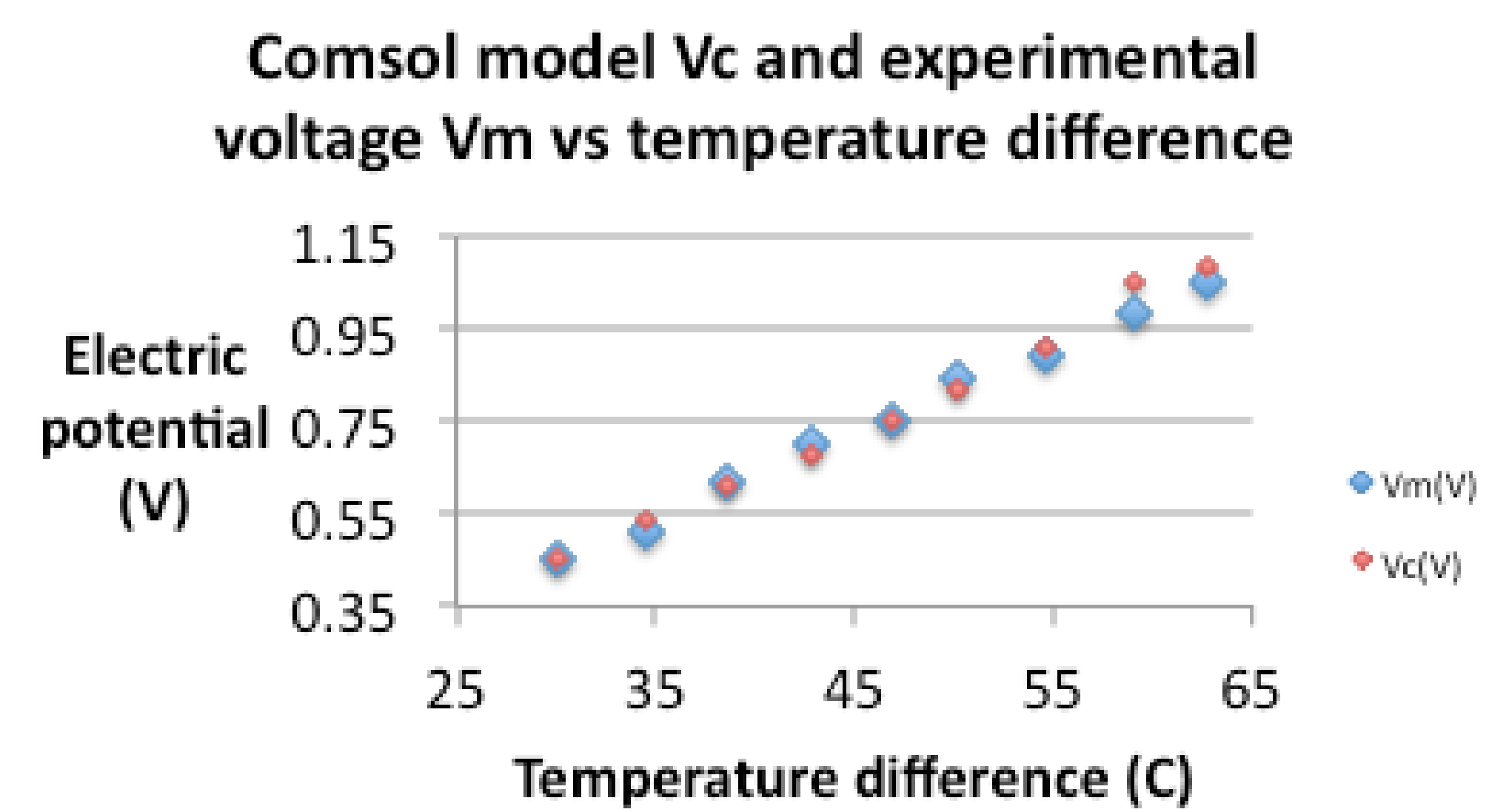


Figure 4. Comsol calculations versus experimental electrical voltage values for a range of temperature differences between the hot and cold faces of the thermoelectric generator.

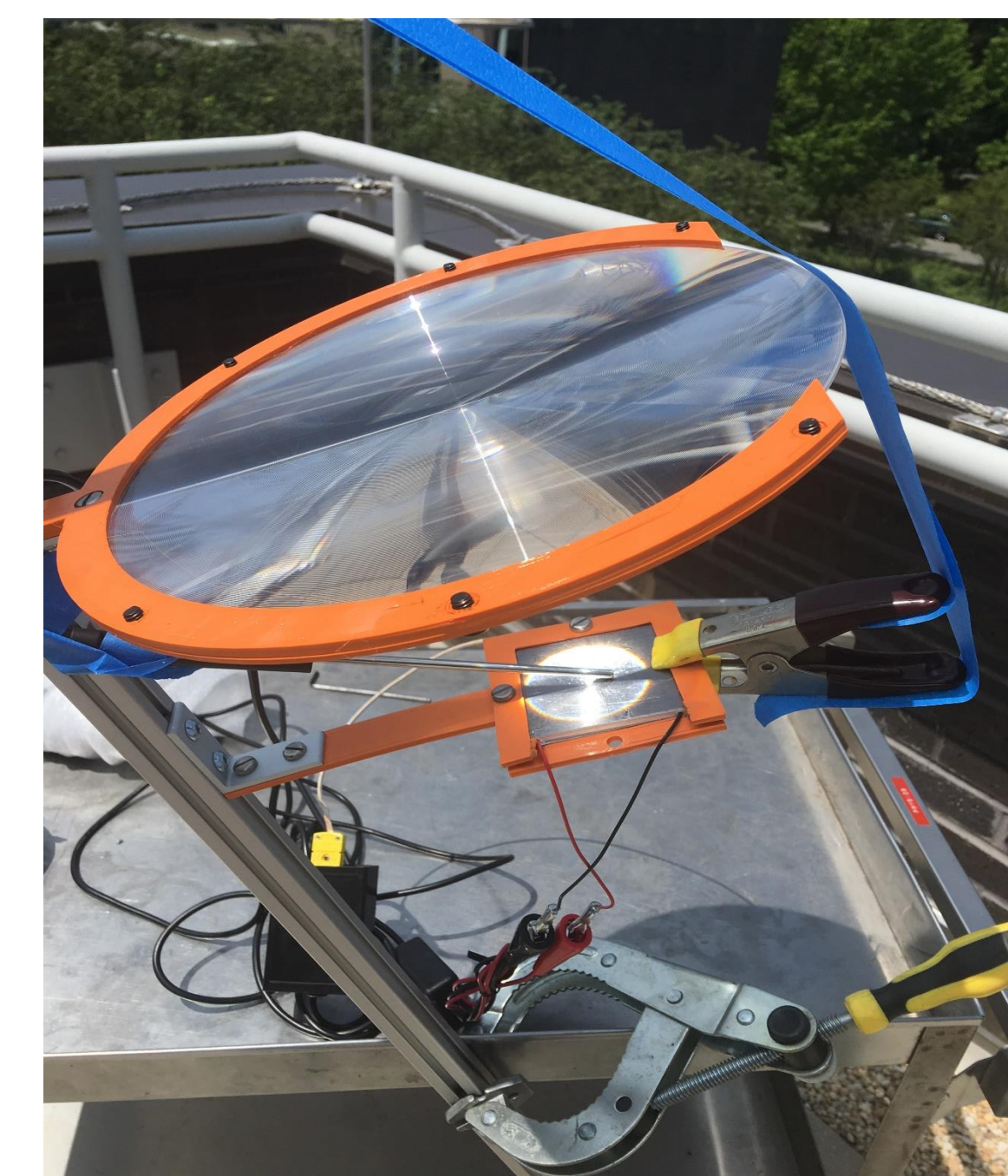


Figure 5. Experimental set up for a TEG heated by sunlight through a Fresnel lens

Experimental data was acquired on a 5cmx5cm, 19 Wat, 4V output module using a 26cm focal distance Fresnel lens, 22 cm in diameter. The mirror was positioned so that the light projected across the module is maximized as shown in Fig. 5. Over a three hour period, the average voltage recorded was 0.25V and an average temperature difference between the hot and cold face was 6 degrees Celsius. The data will be used as input in a Comsol model of a thermoelectric system using a Fresnel lens currently being developed.

**CONCLUSIONS:** Comsol Multiphysics software is an invaluable tool that can be incorporated as early as the sophomore year of the engineering physics undergraduate curriculum. This can be accomplished by developing examples of 3D geometries and virtual operations with geometries, solving fundamental problems in mechanics, heat transfer, optics, etc at the appropriate class level and incorporating modeling, 3D printing and prototype testing in the undergraduate research. The project presented here spurred the interest in Comsol Multiphysics of several physics majors who will work in their junior year on several Comsol projects based on experimental measurement and 3D printing.

## REFERENCES:

1. [www.comsol.com](http://www.comsol.com), Learning Center Application examples.
2. Daniela Buna, Ph.D., Daniel Tafone, Lejla Hohxa, **Thermoelectric Generators With Air/water Cooling And Novel Metamaterial Components**, Poster presentation, Comsol Conference Lausanne, Switzerland, October 2018.