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**PROFESSOR SCHULZ'S DIDACTIC APPLICATION  
OF ZEEMAN'S CATASTROPHE MACHINE  
EXPERIMENTAL DATA FOR COMPETITION IN STATICS CLASSES.  
1<sup>ST</sup> APPLIED AT AUBURN UNIVERSITY, SPRING 2021, AL, USA**

**PLEASE CITE CC**

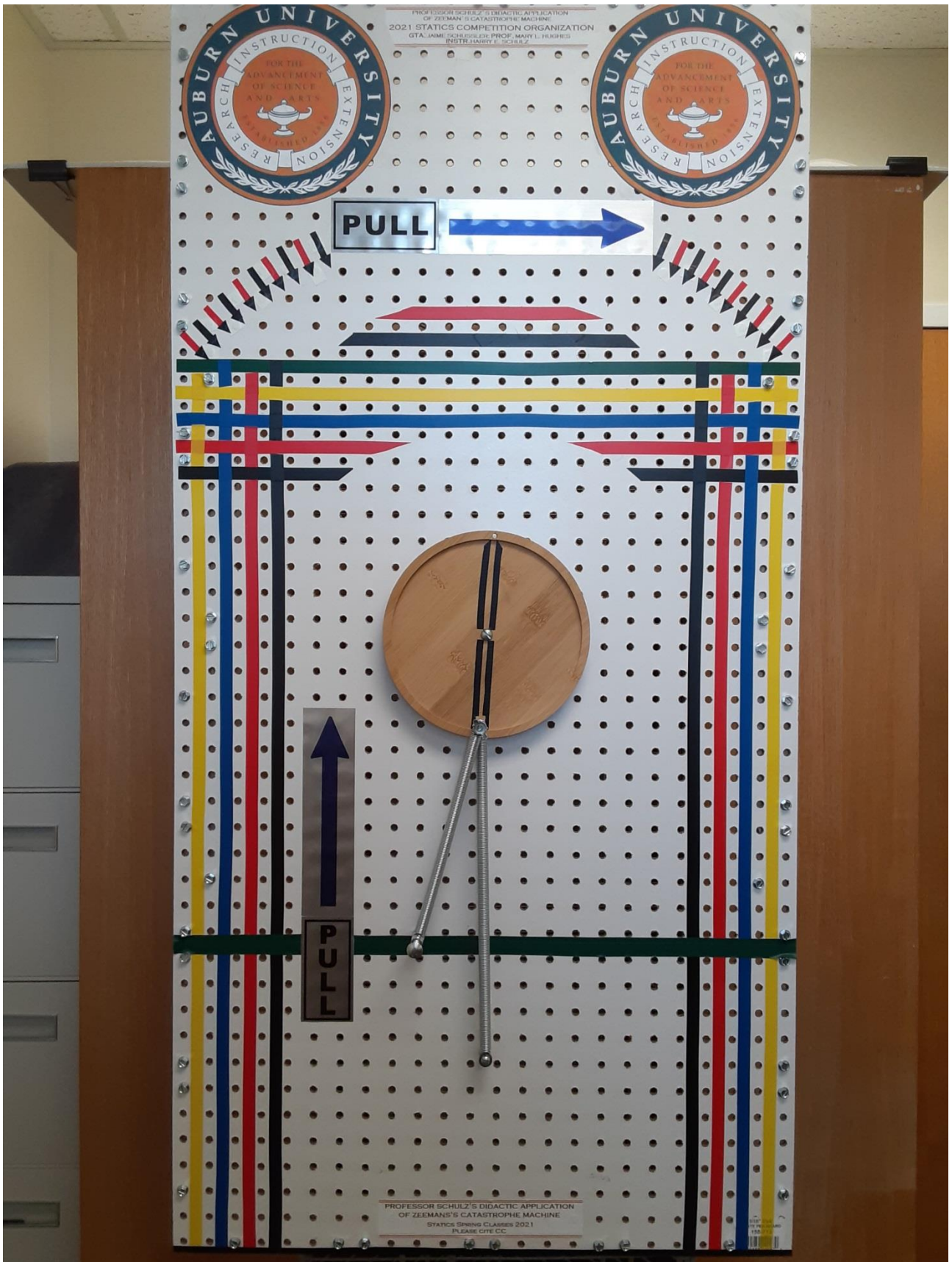
**SCHULZ, H.E.; SIMÕES, A.L.A. (2021) DIDACTIC APPLICATION OF ZEEMAN'S CATASTROPHE MACHINE: EXPERIMENTAL DATA FOR COMPETITION IN STATICS CLASSES. SPRING TERM 2021. DEPT. OF CIVIL AND ENV. ENGG.. AUBURN UNIVERSITY, AL., USA. COLLABORATION WITH FEDERAL UNIVERSITY OF BAHIA, BRAZIL.**

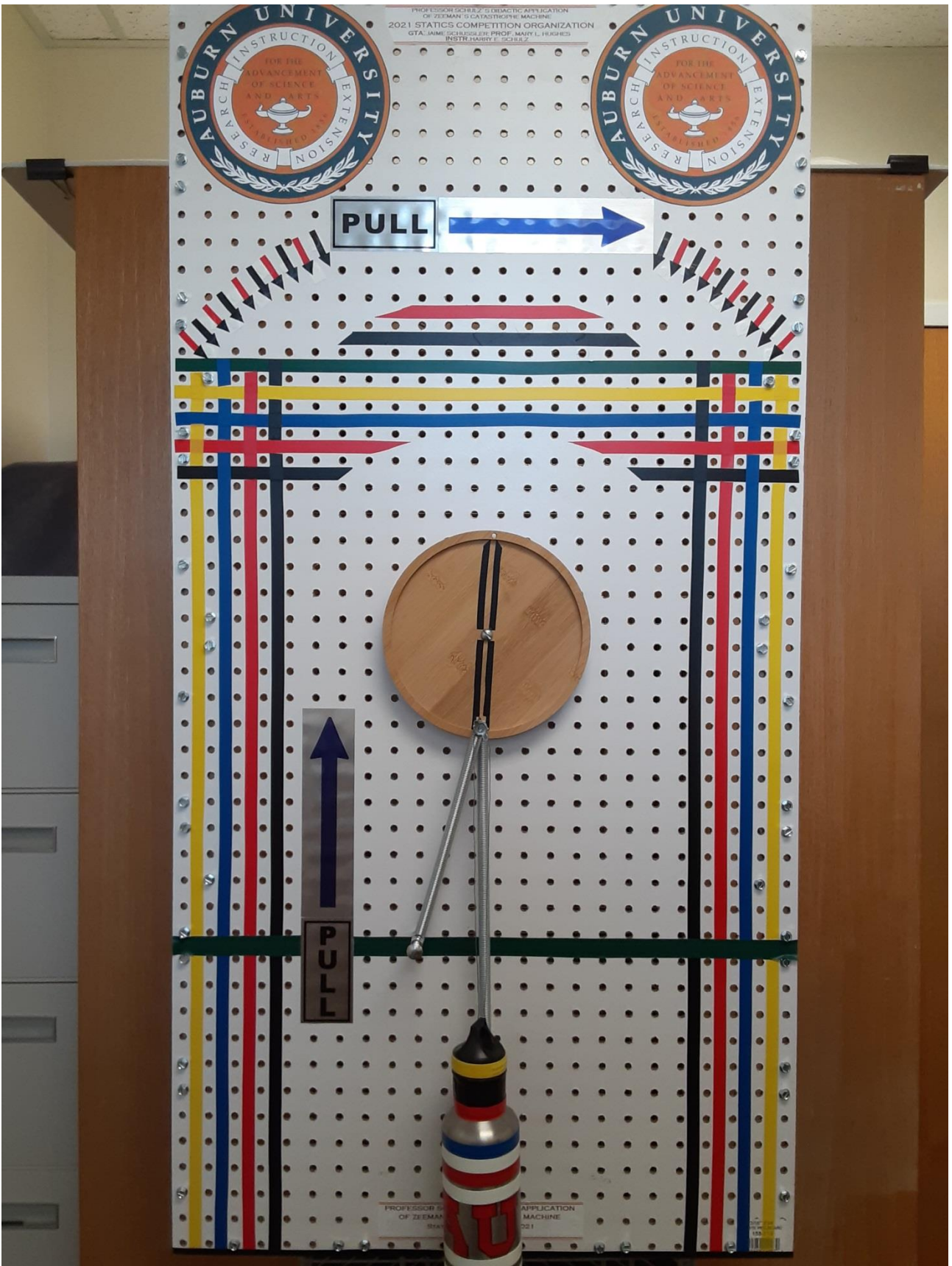


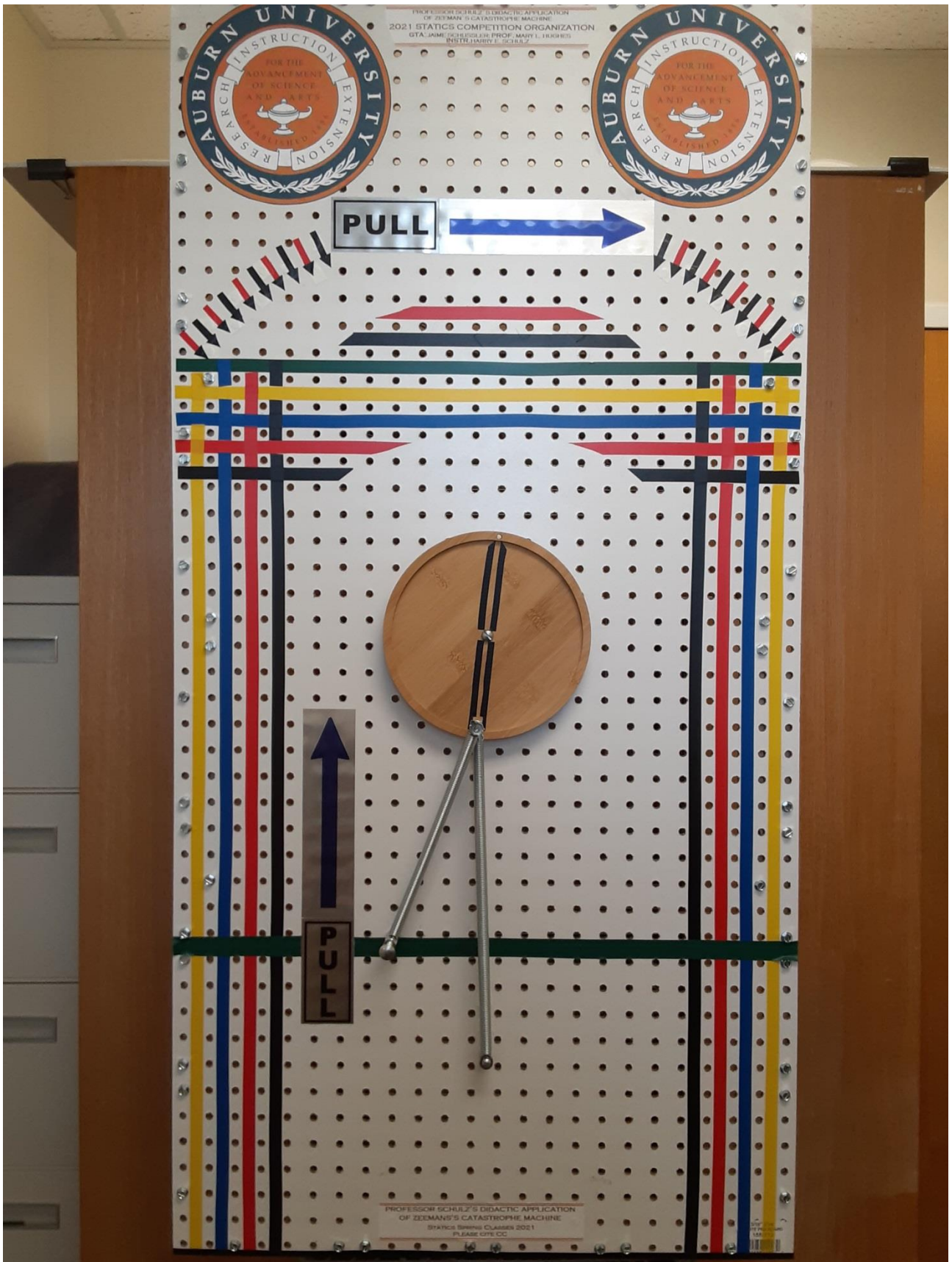
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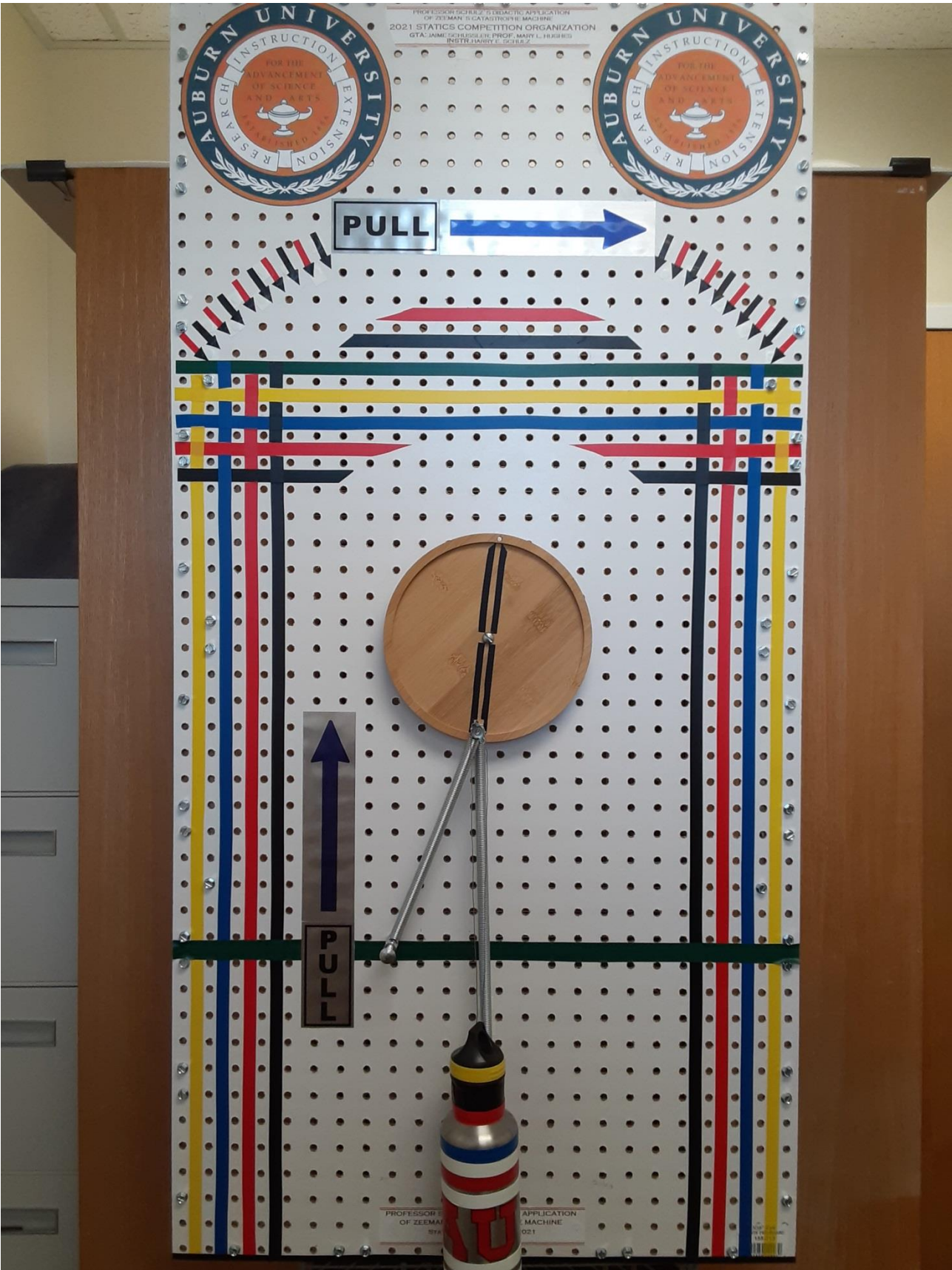


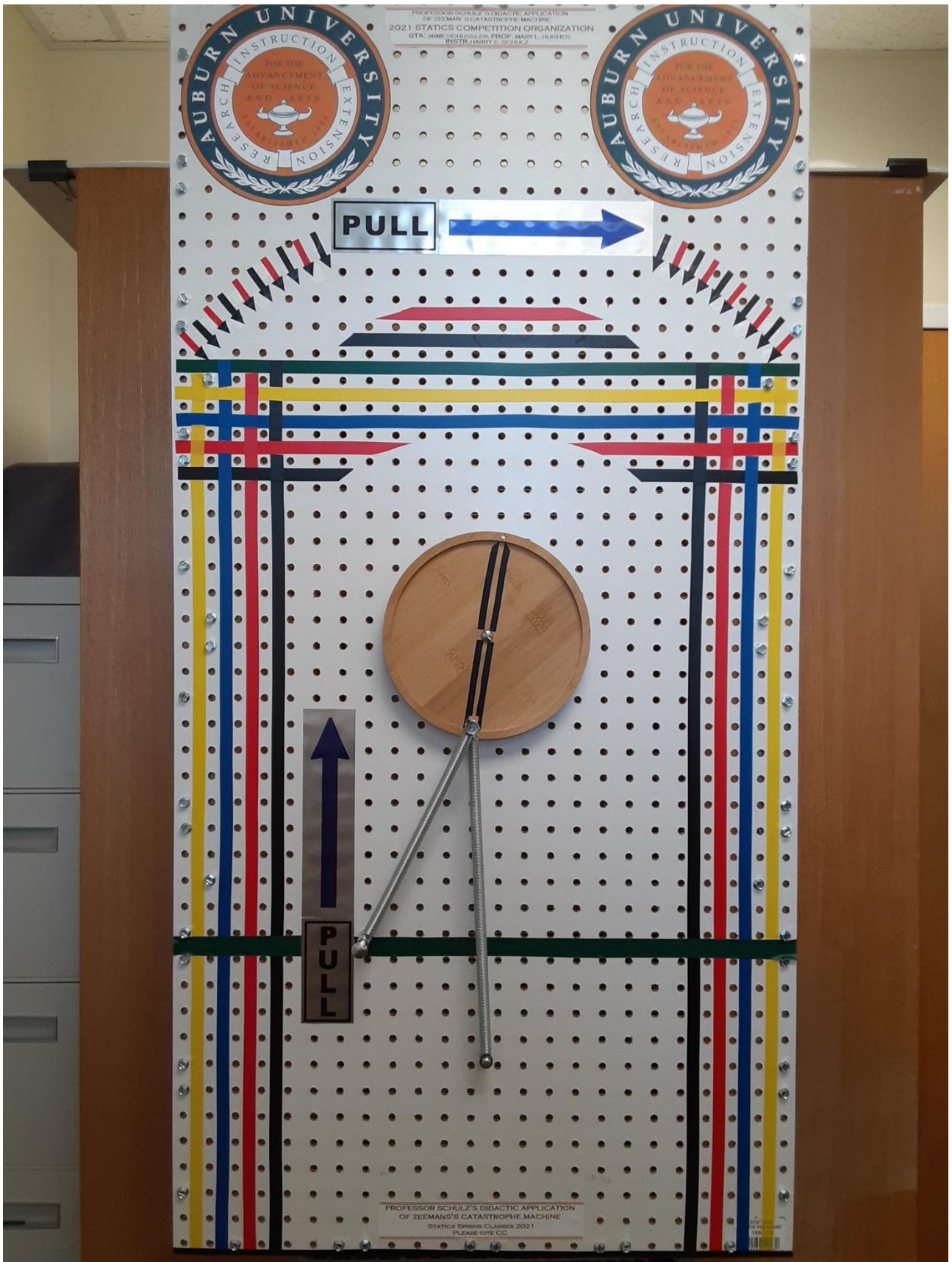
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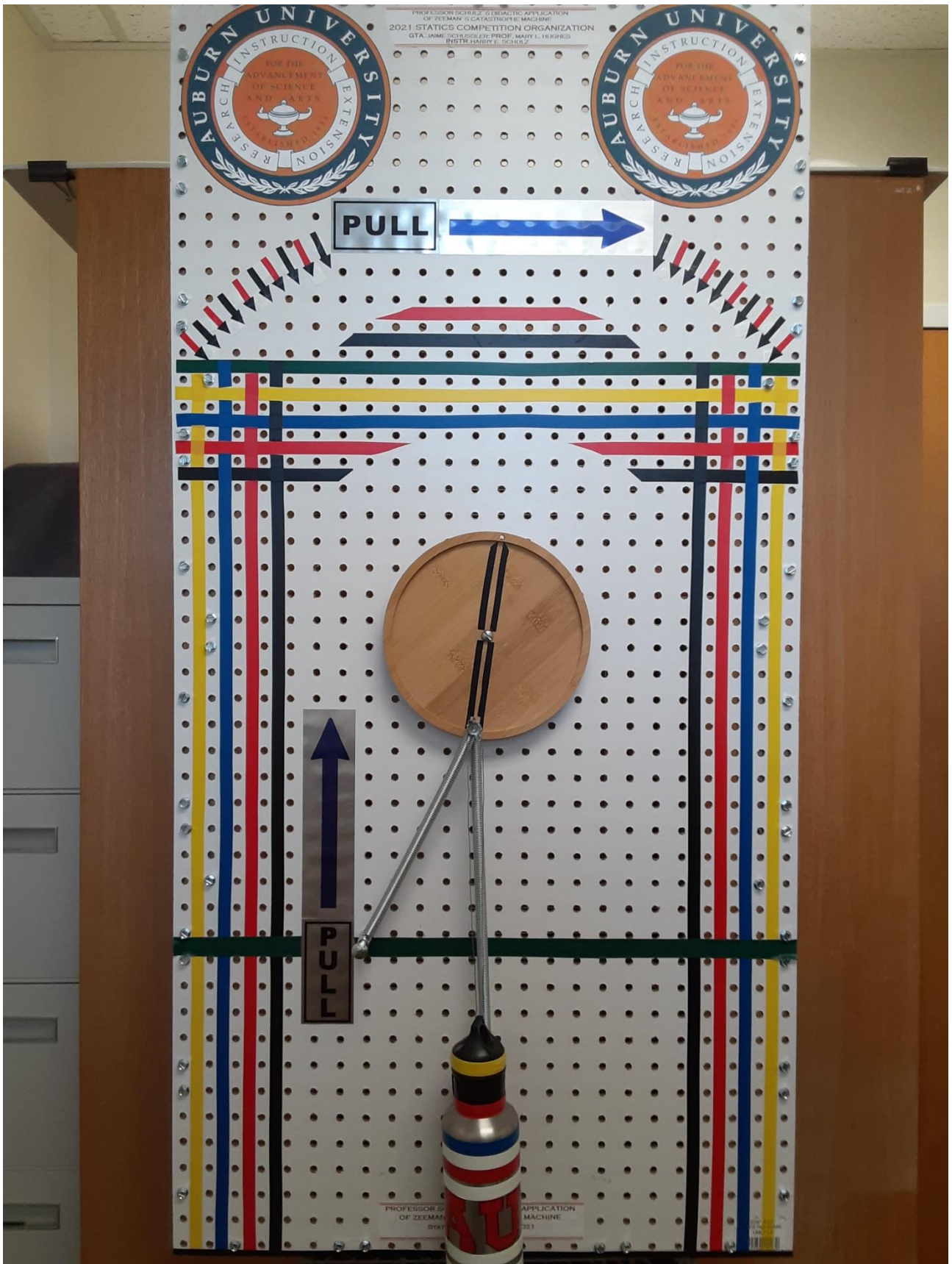


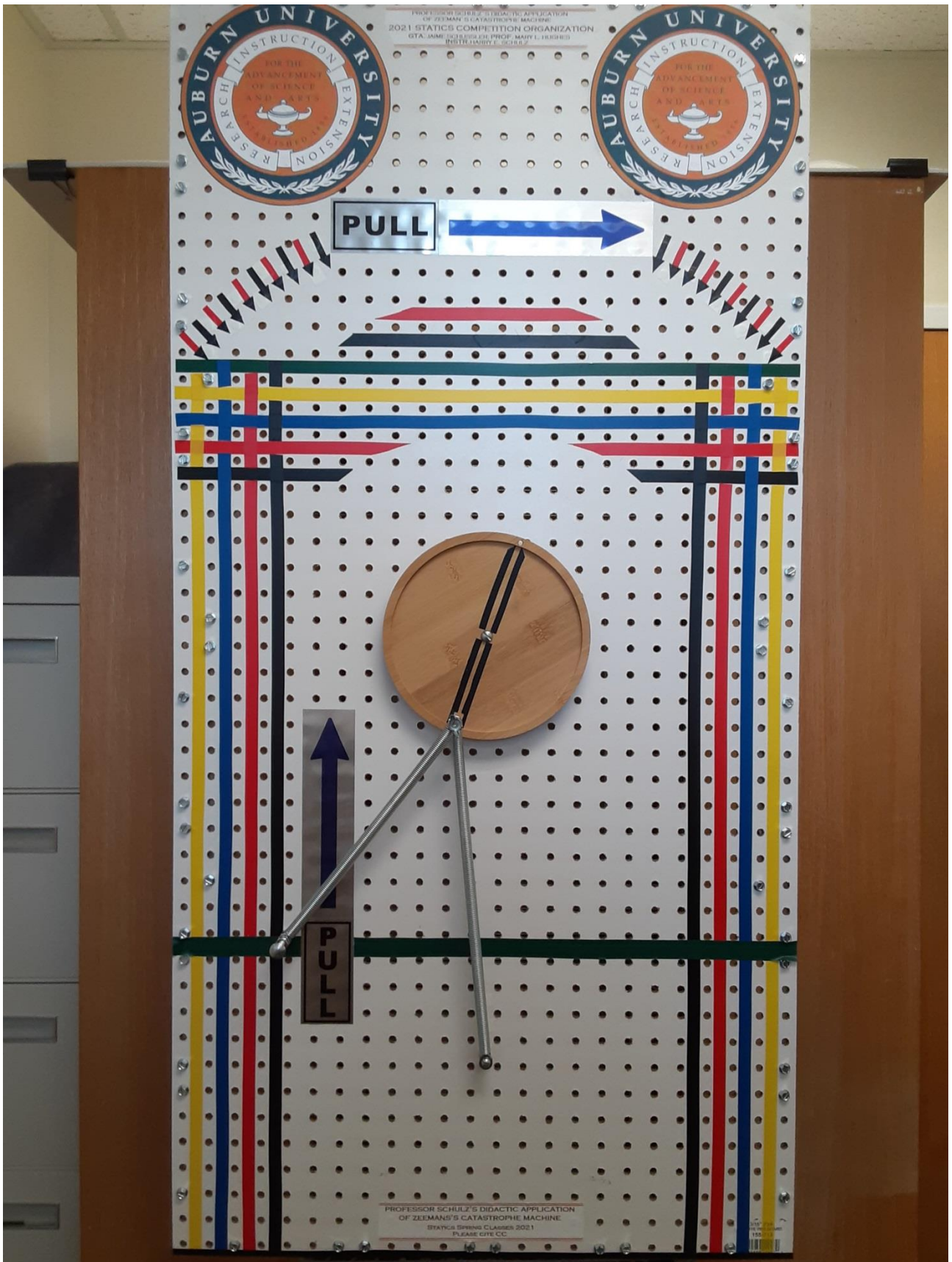




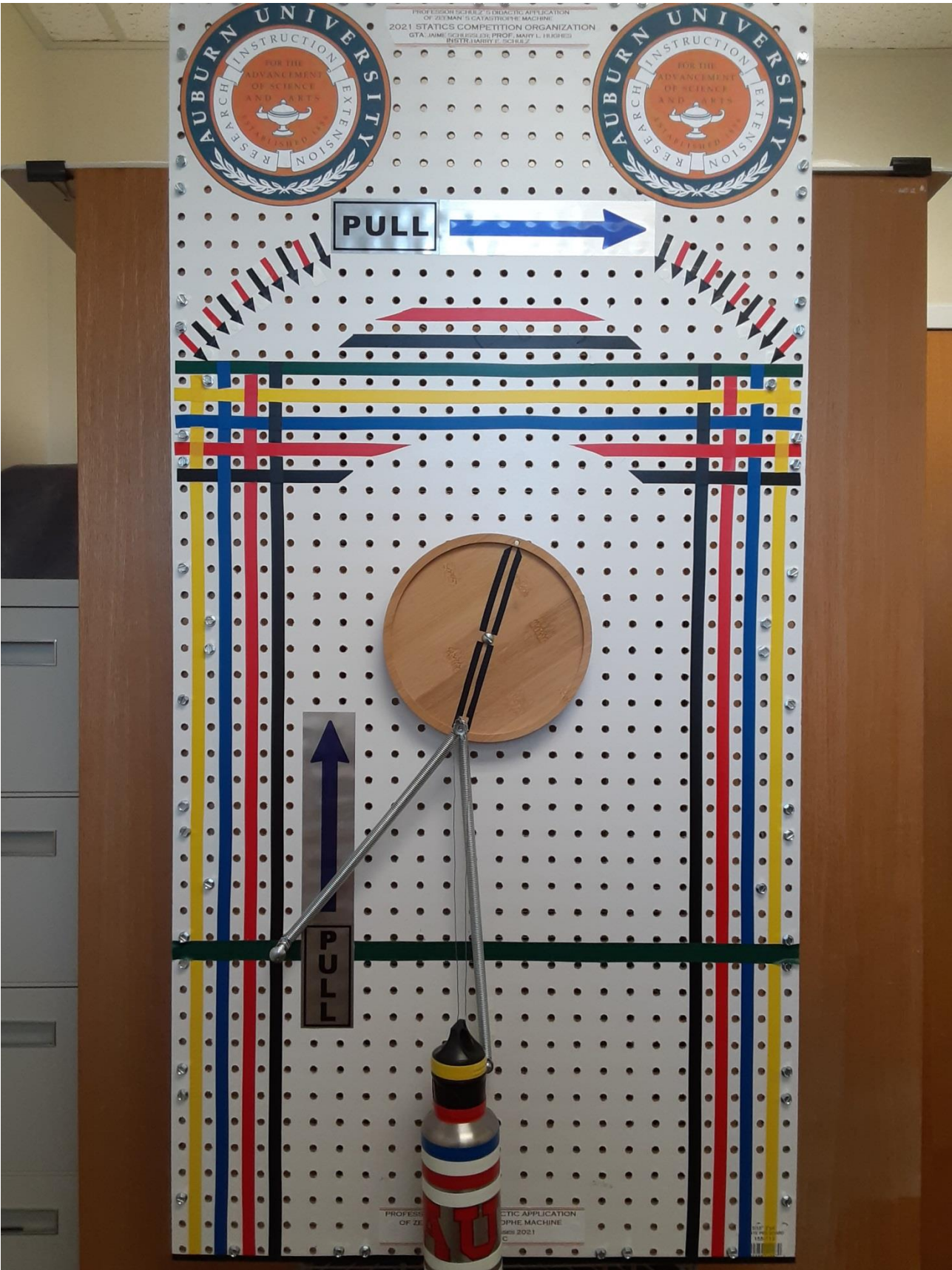


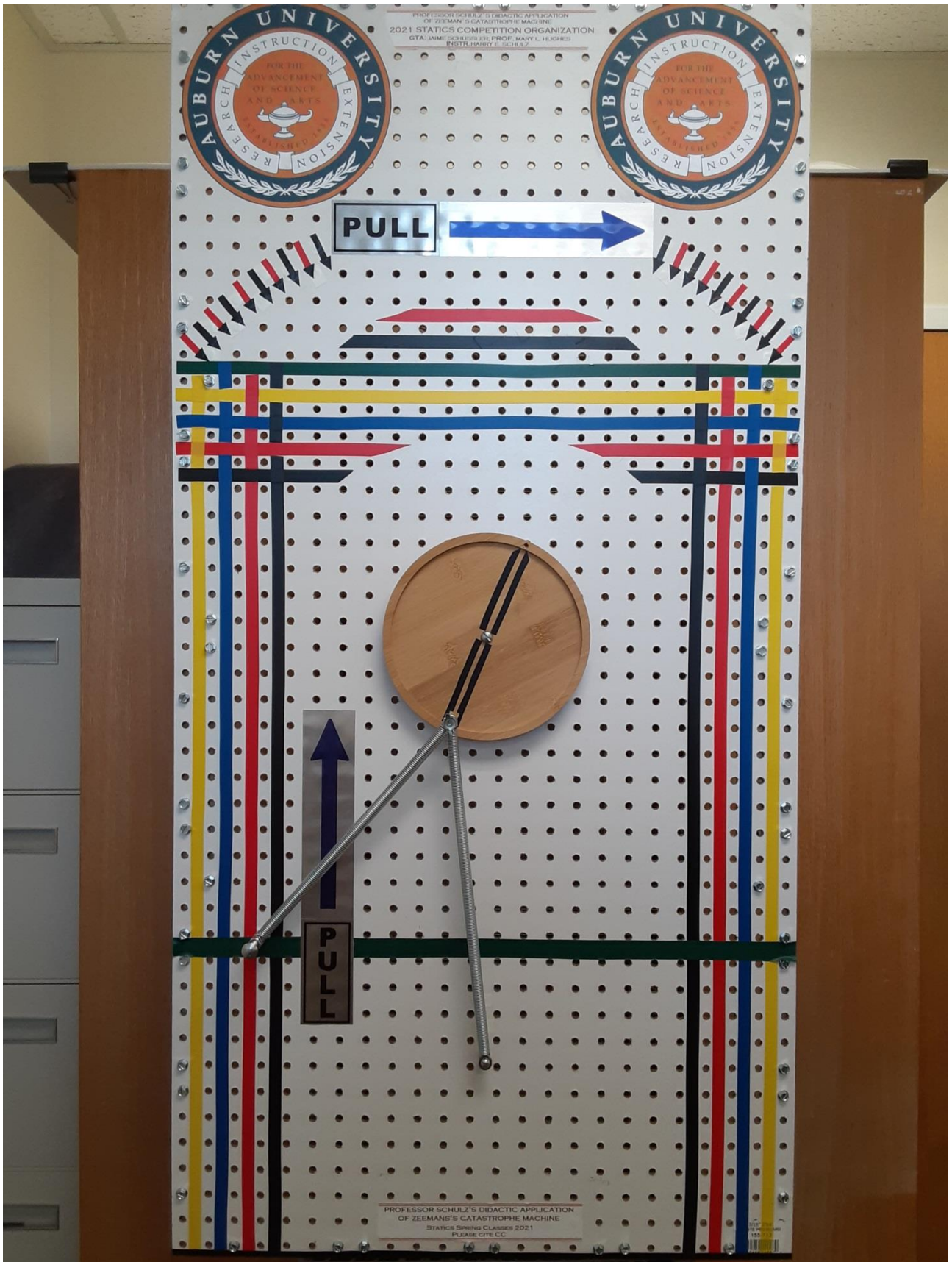


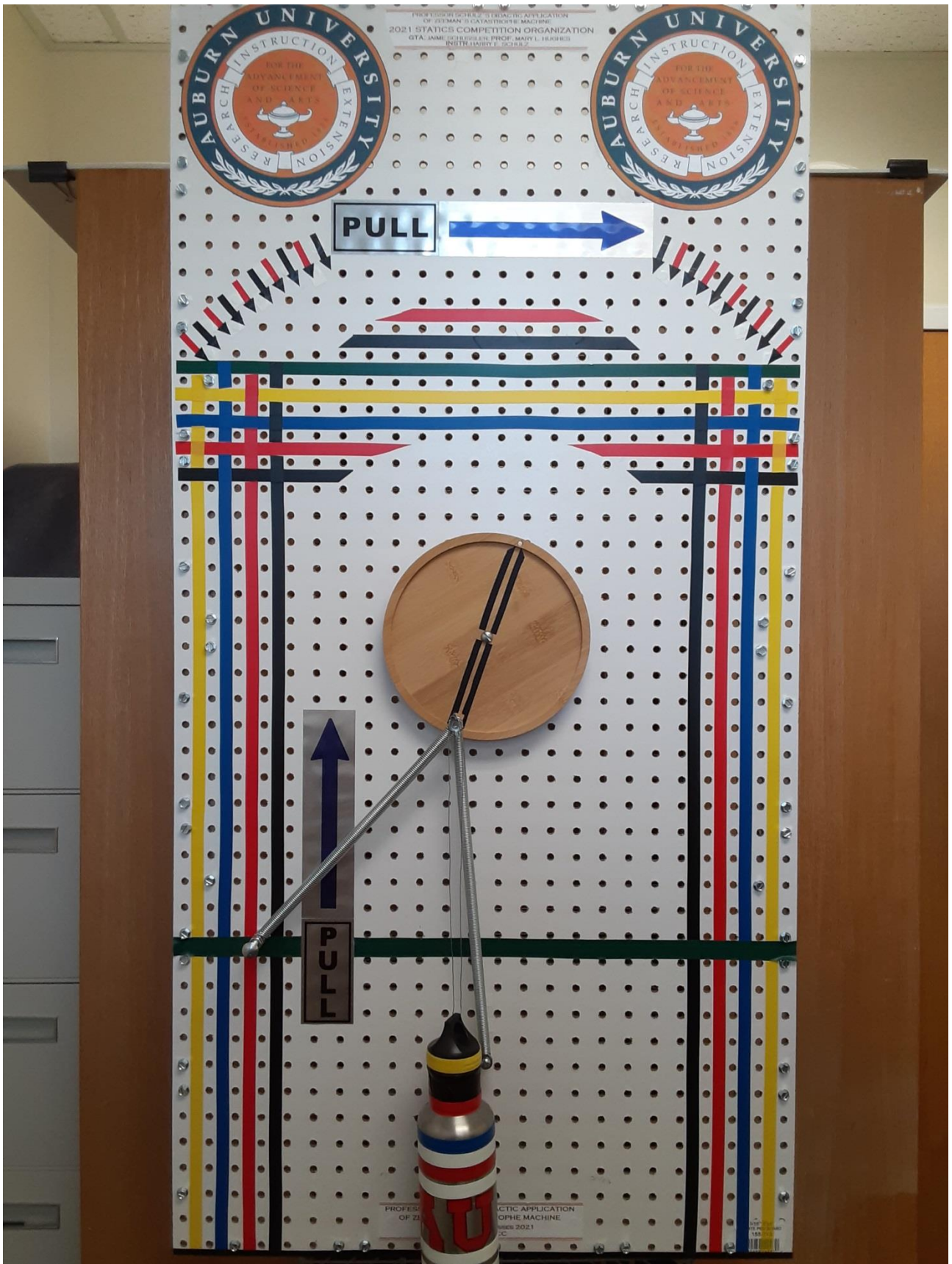


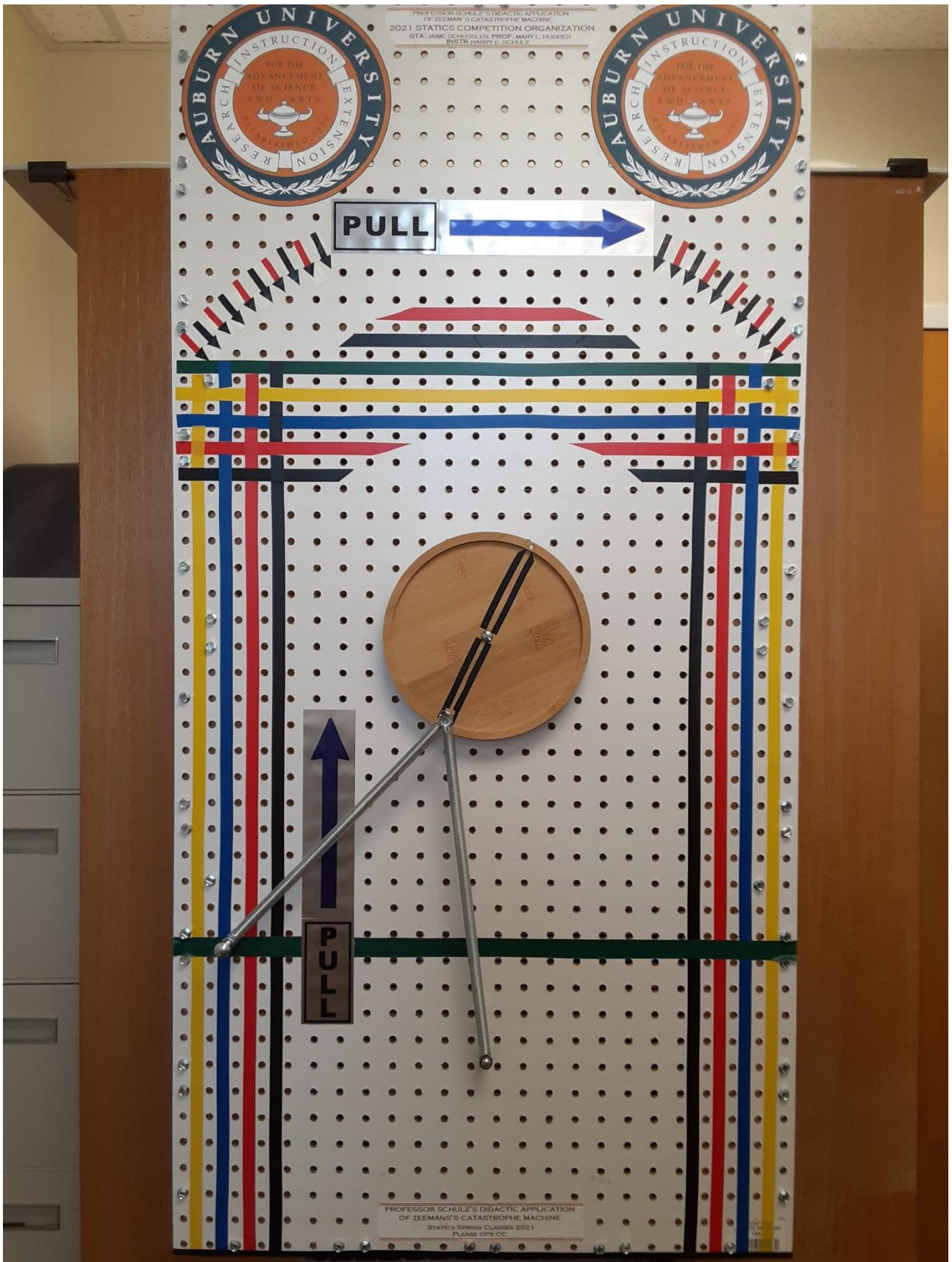


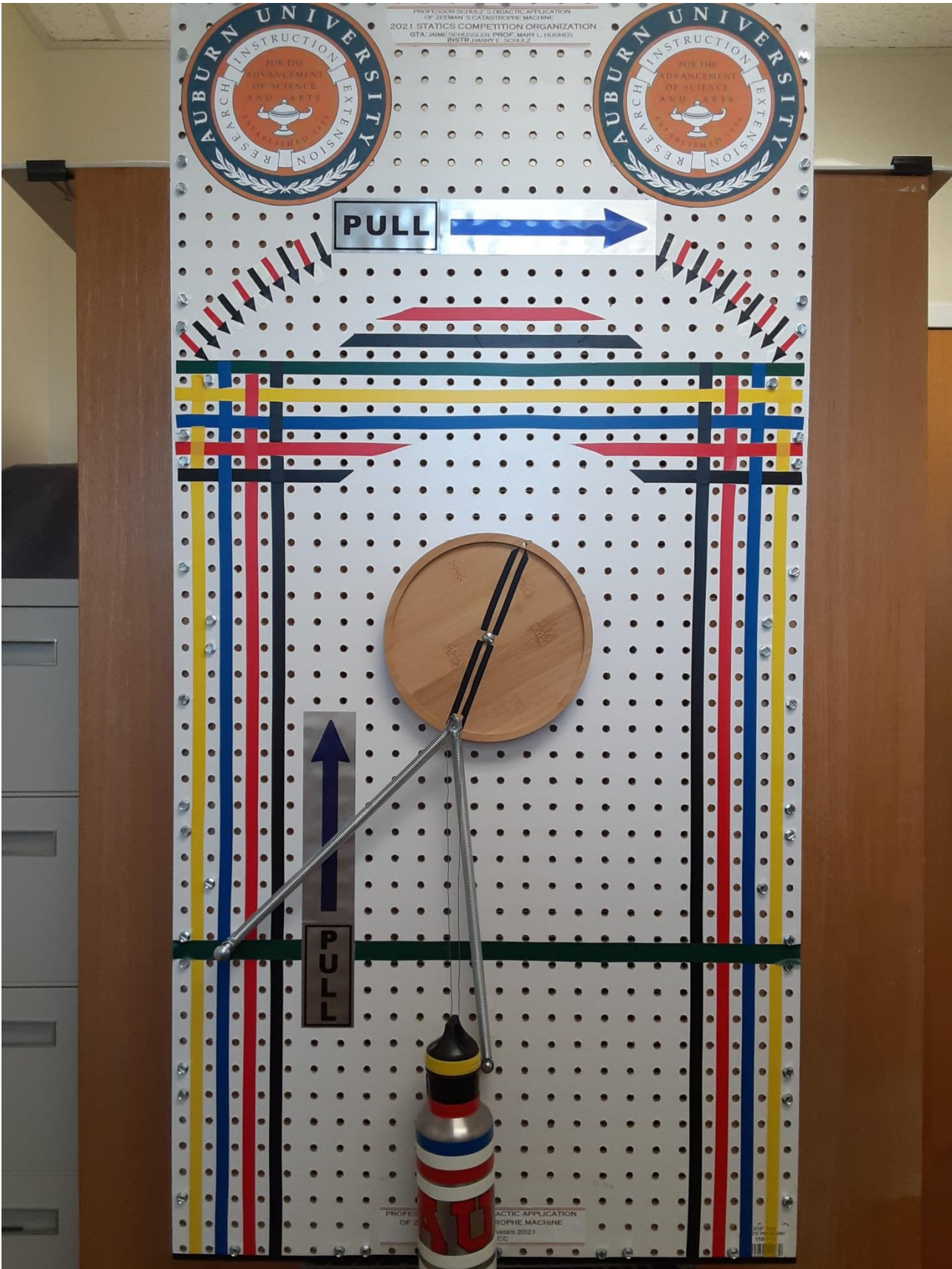


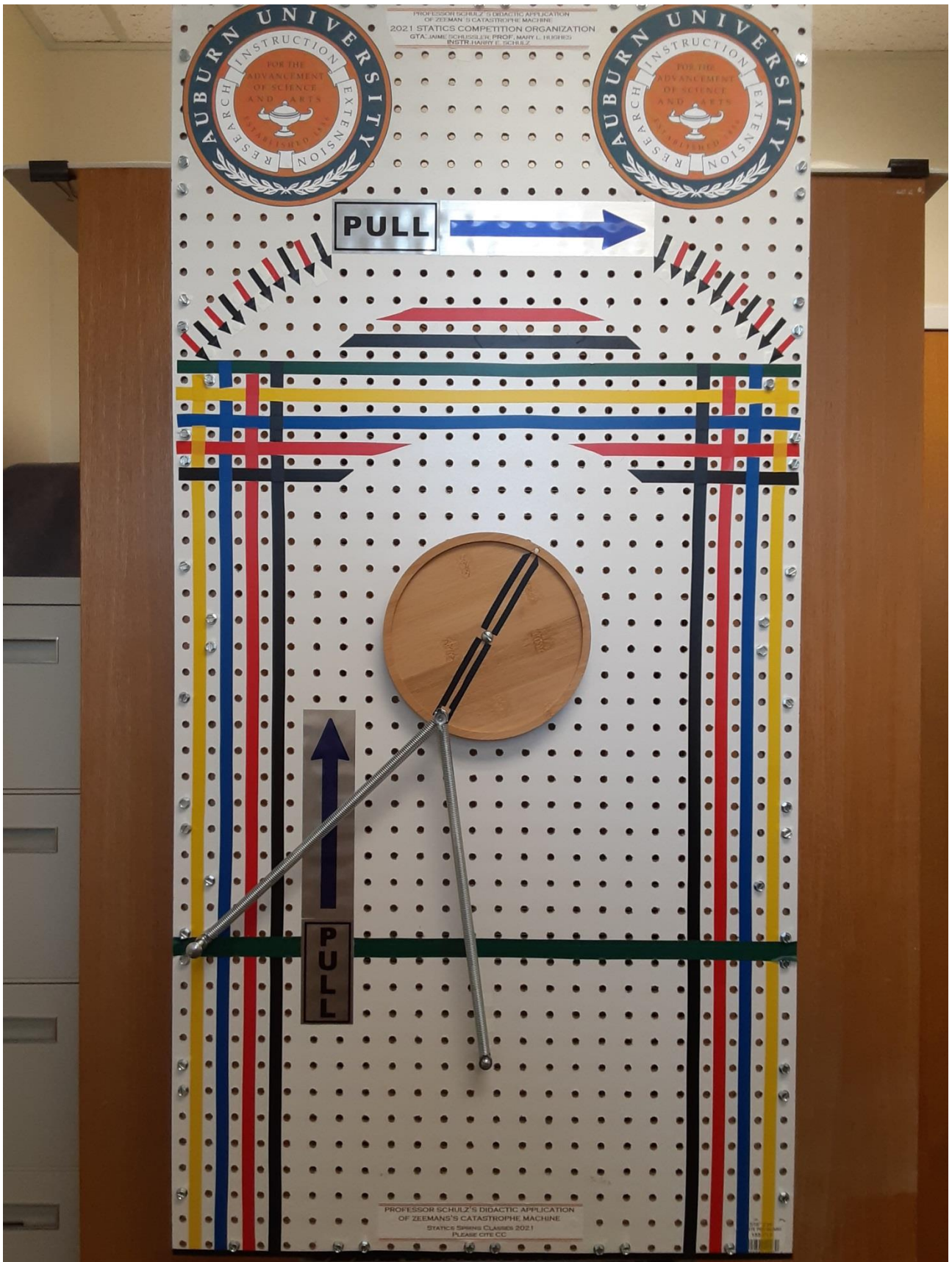


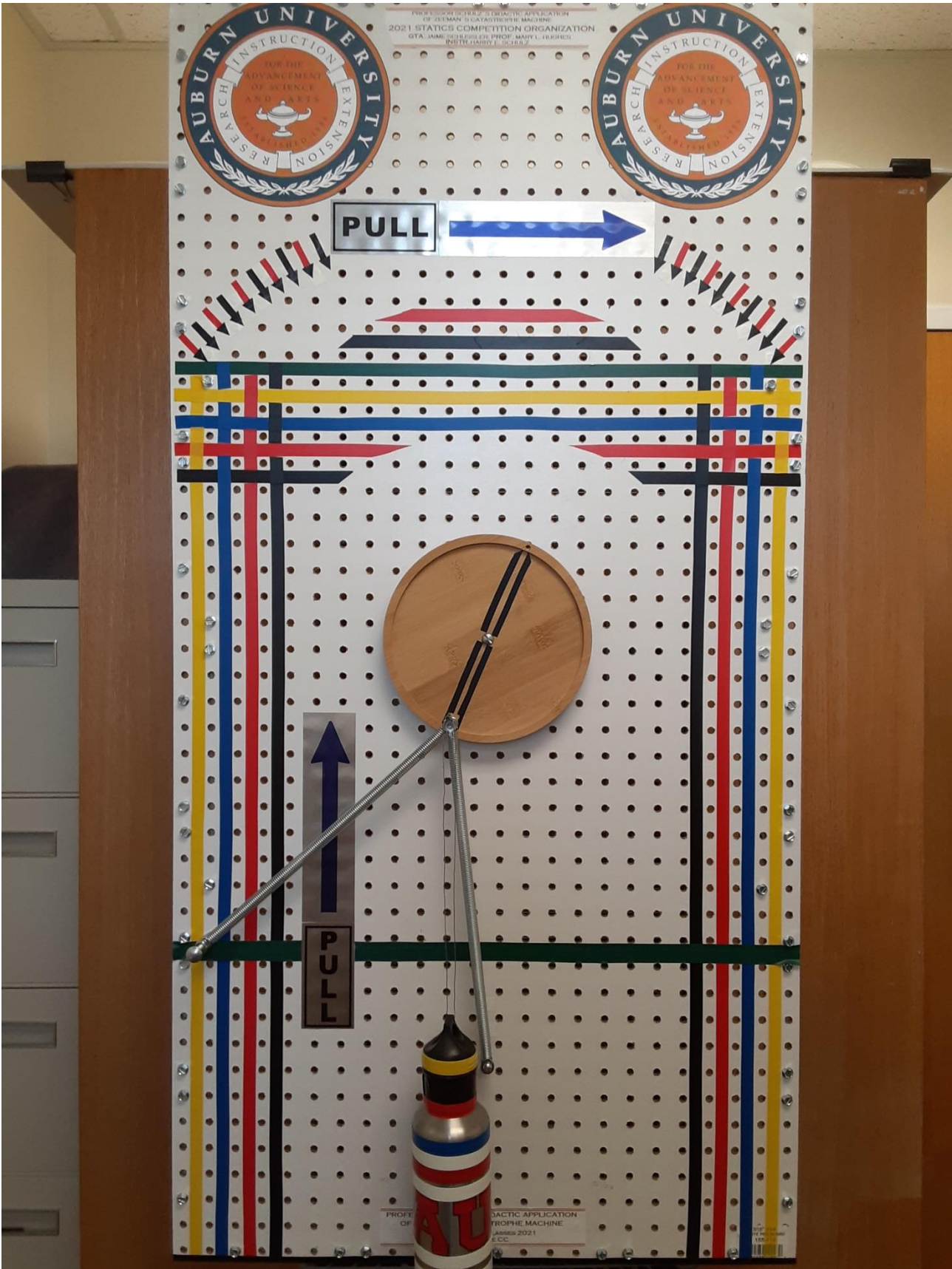


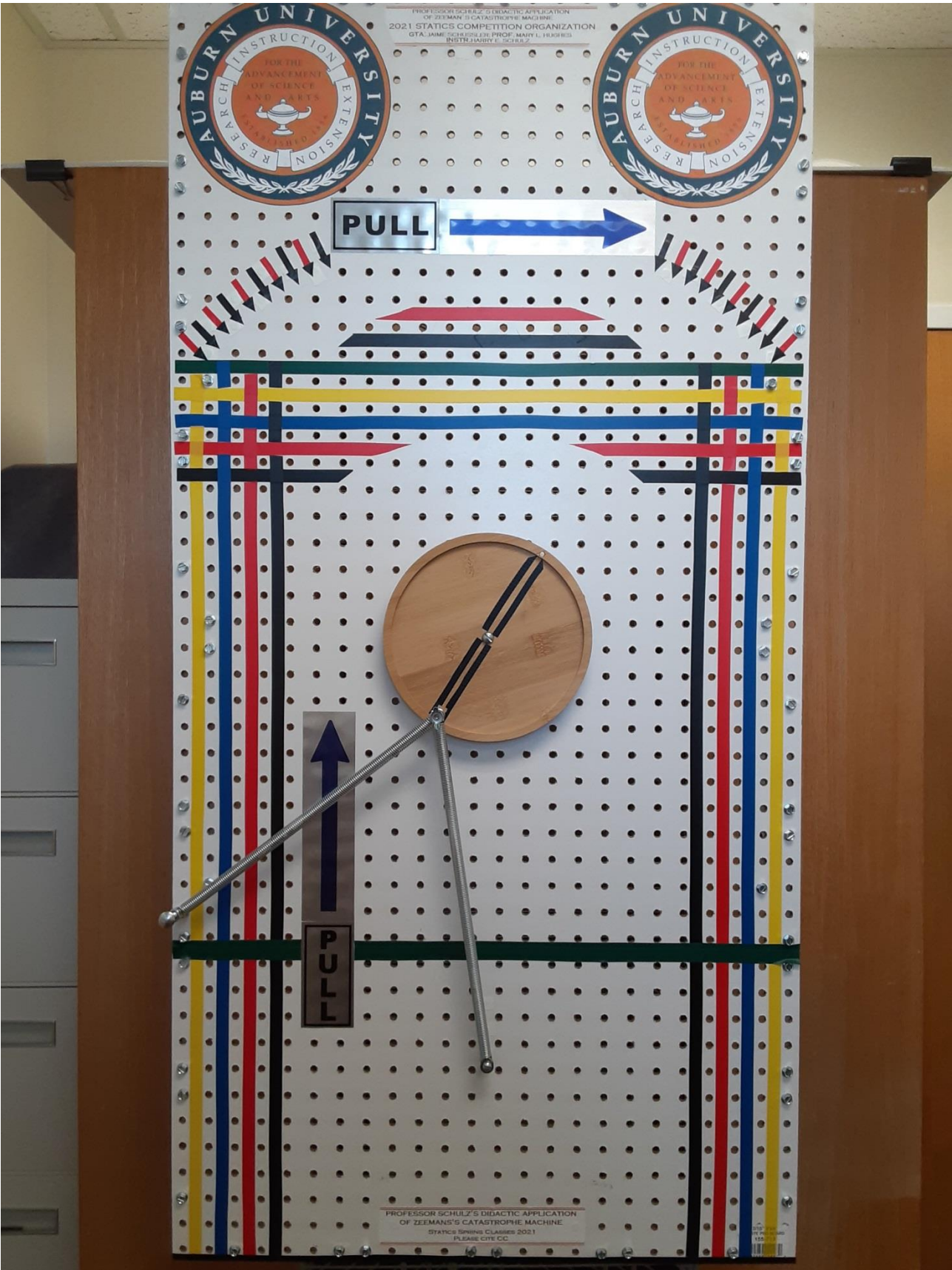




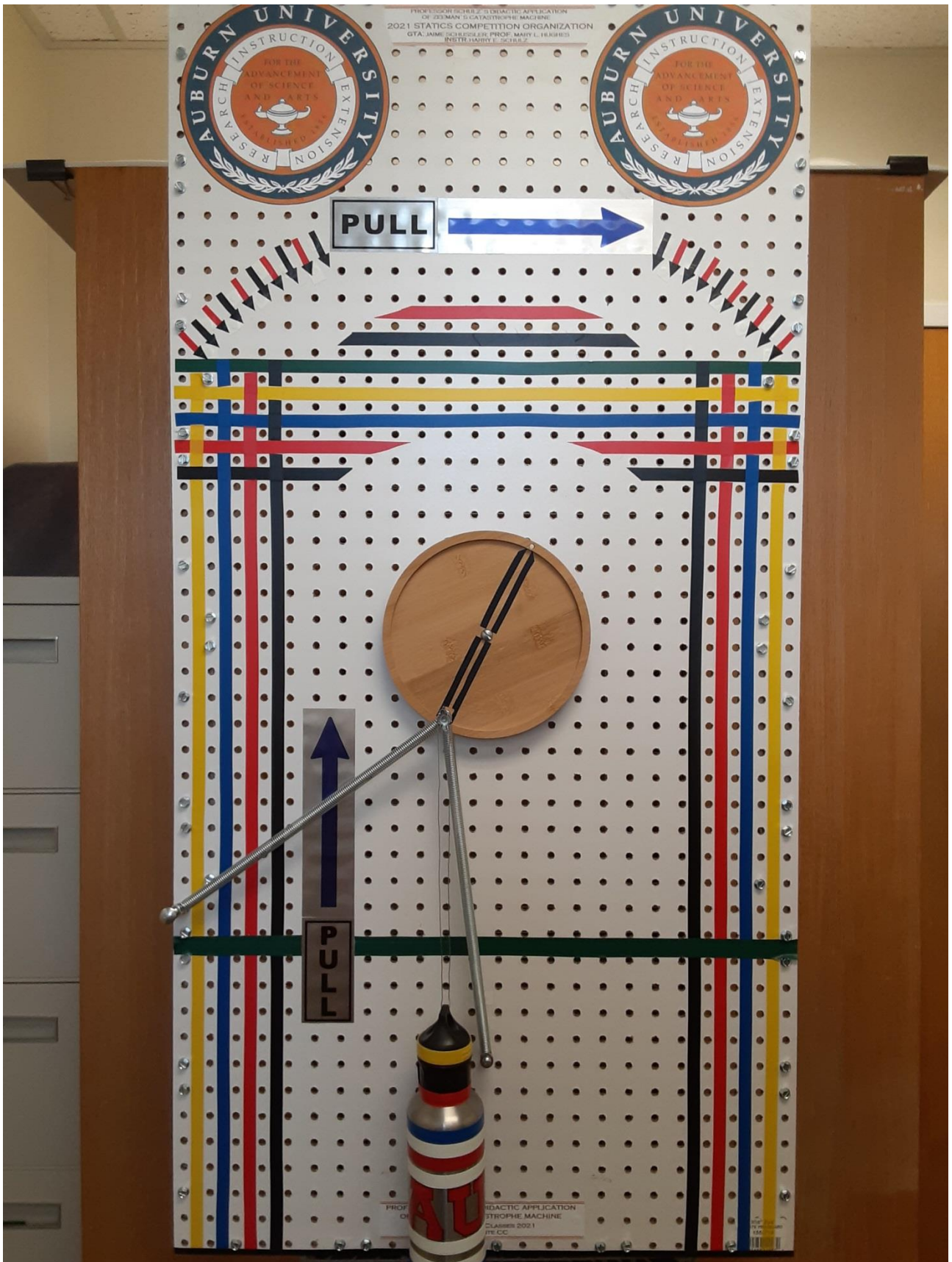


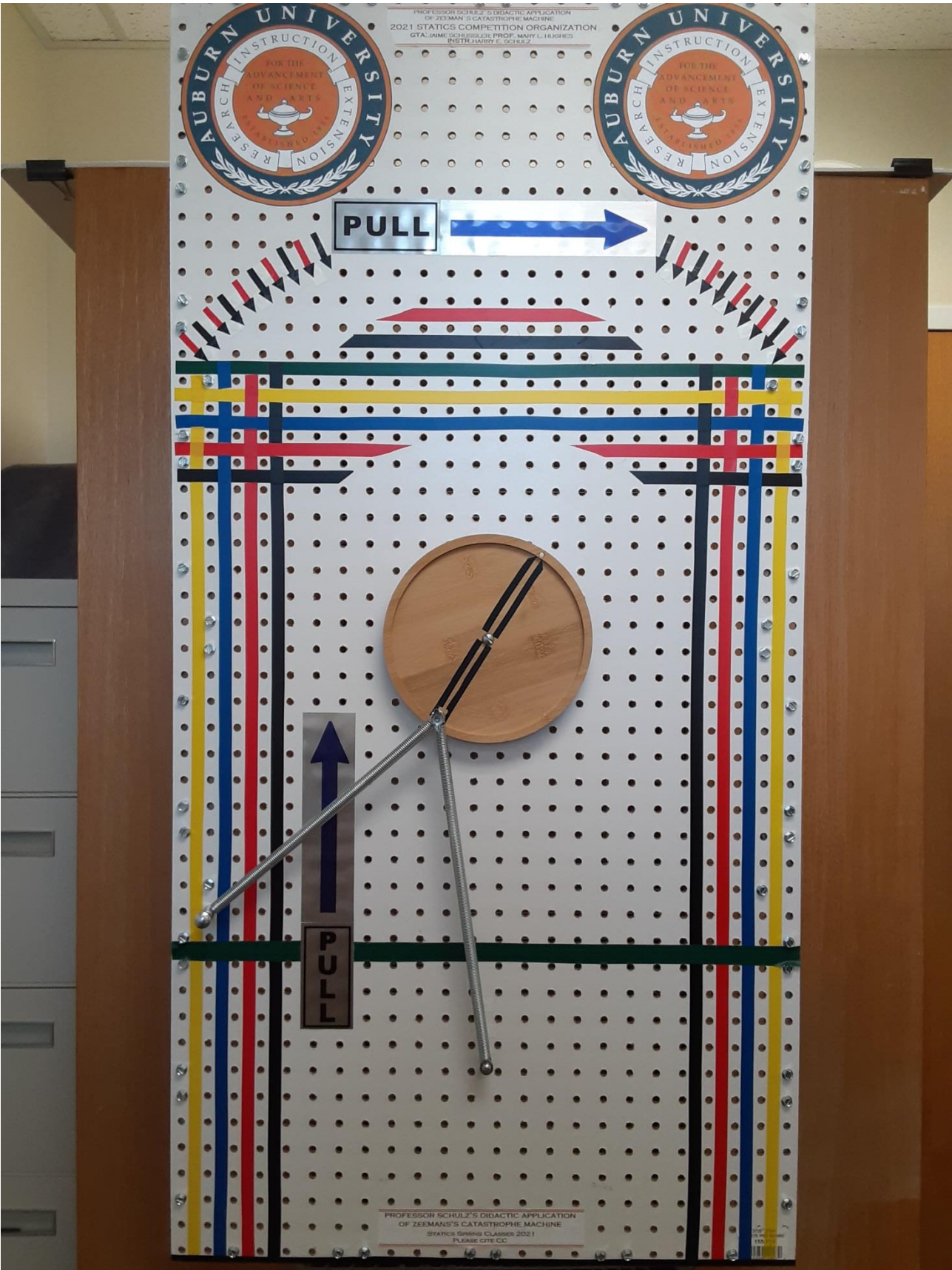


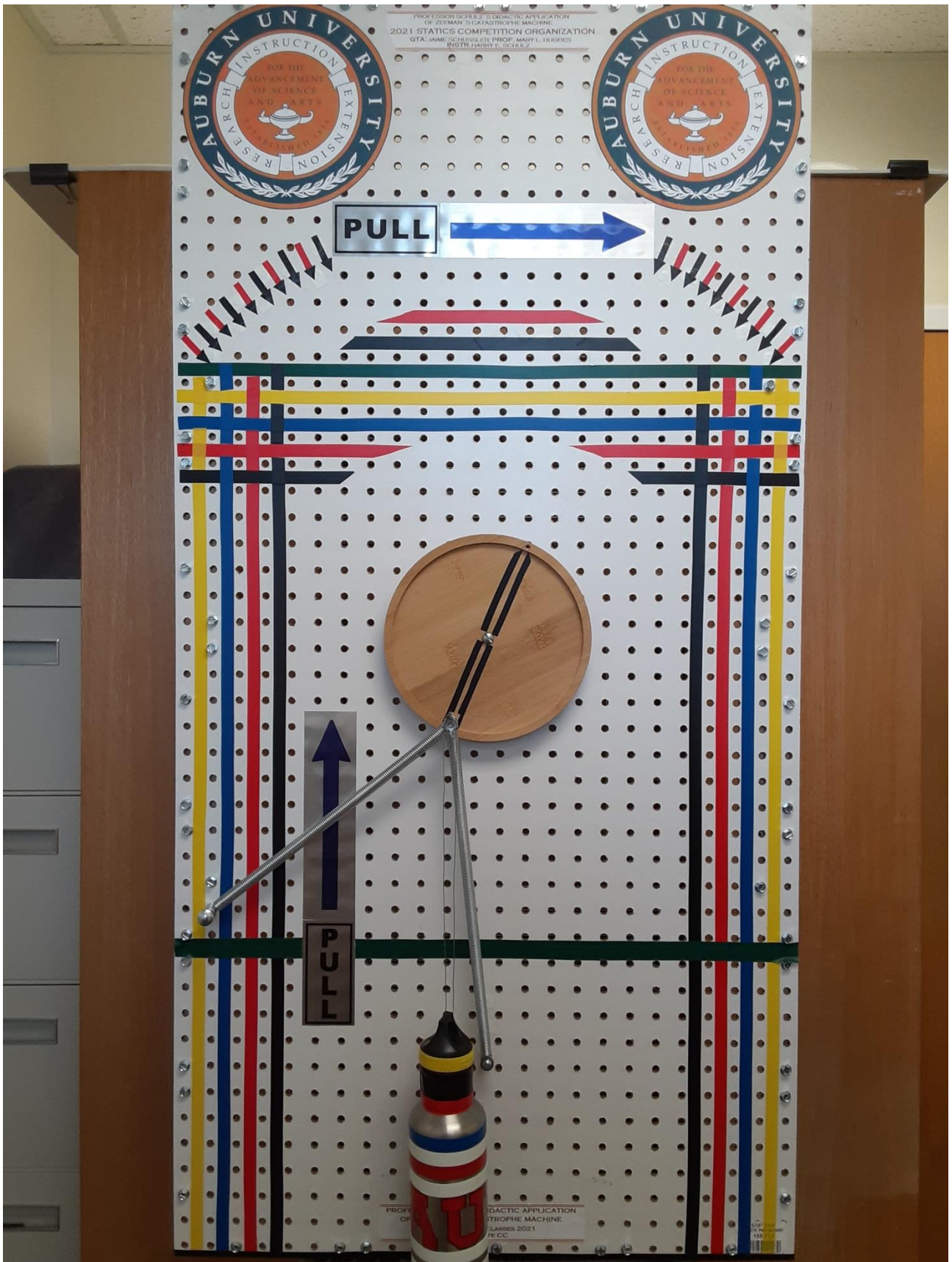


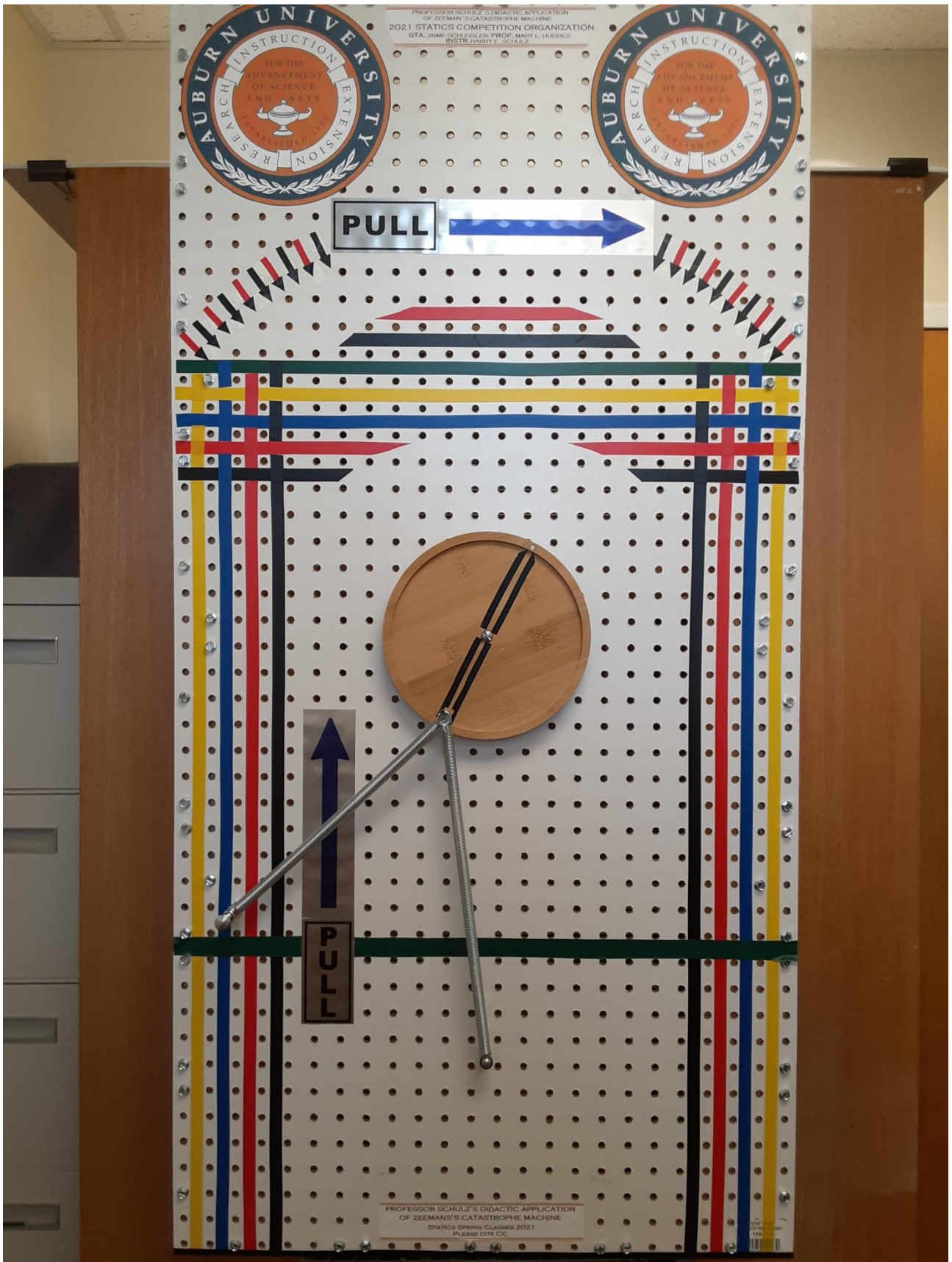


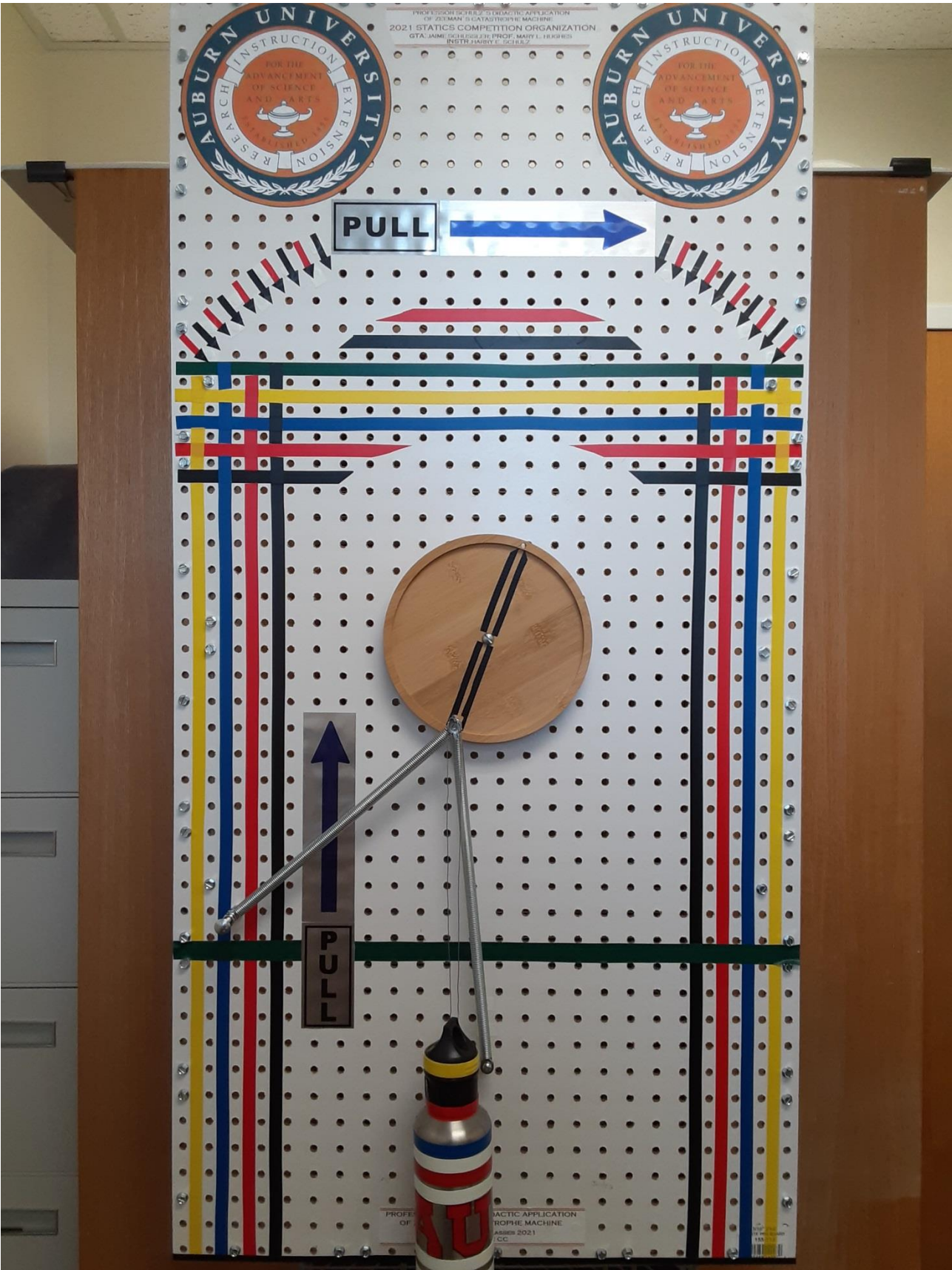


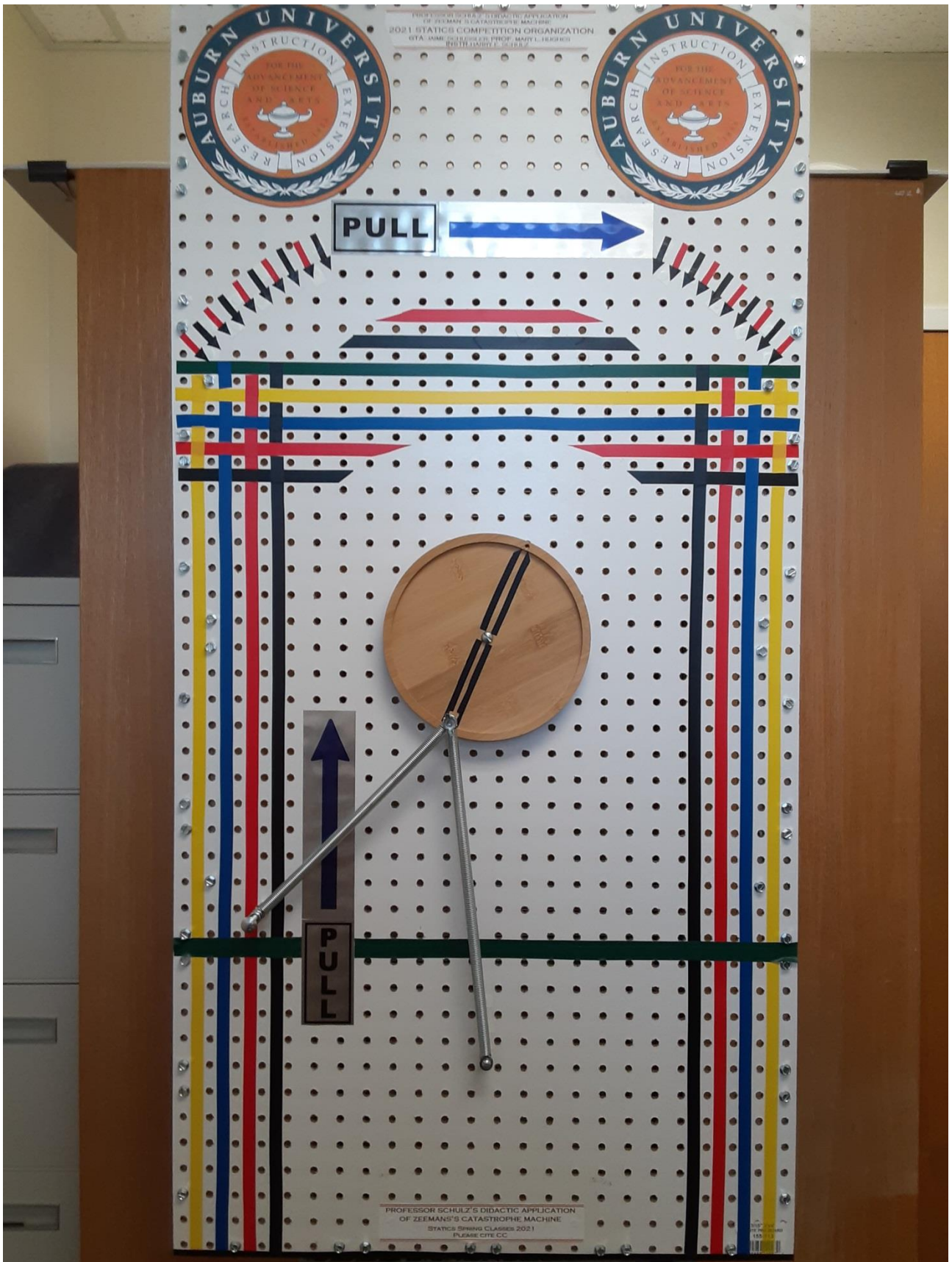


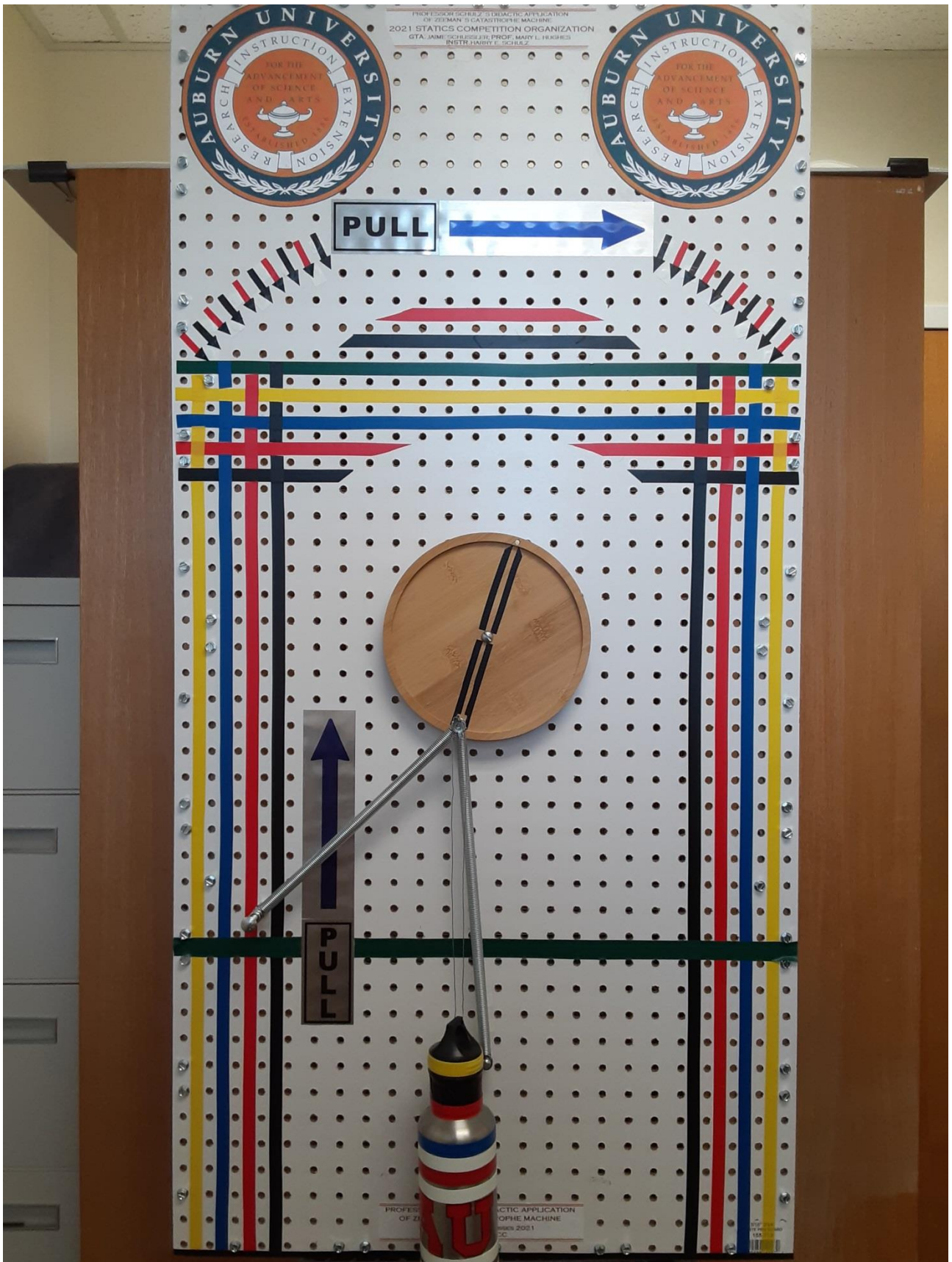


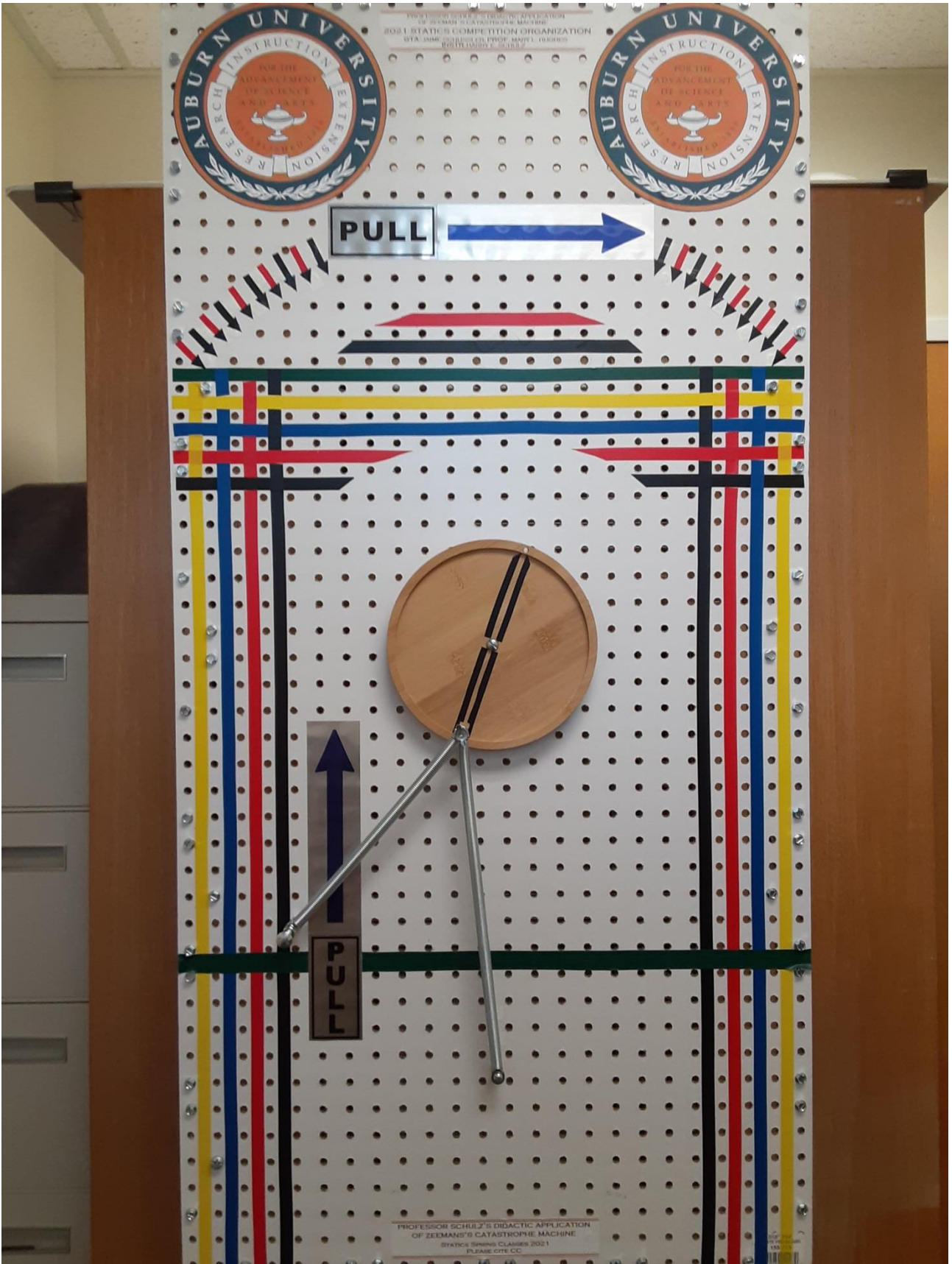




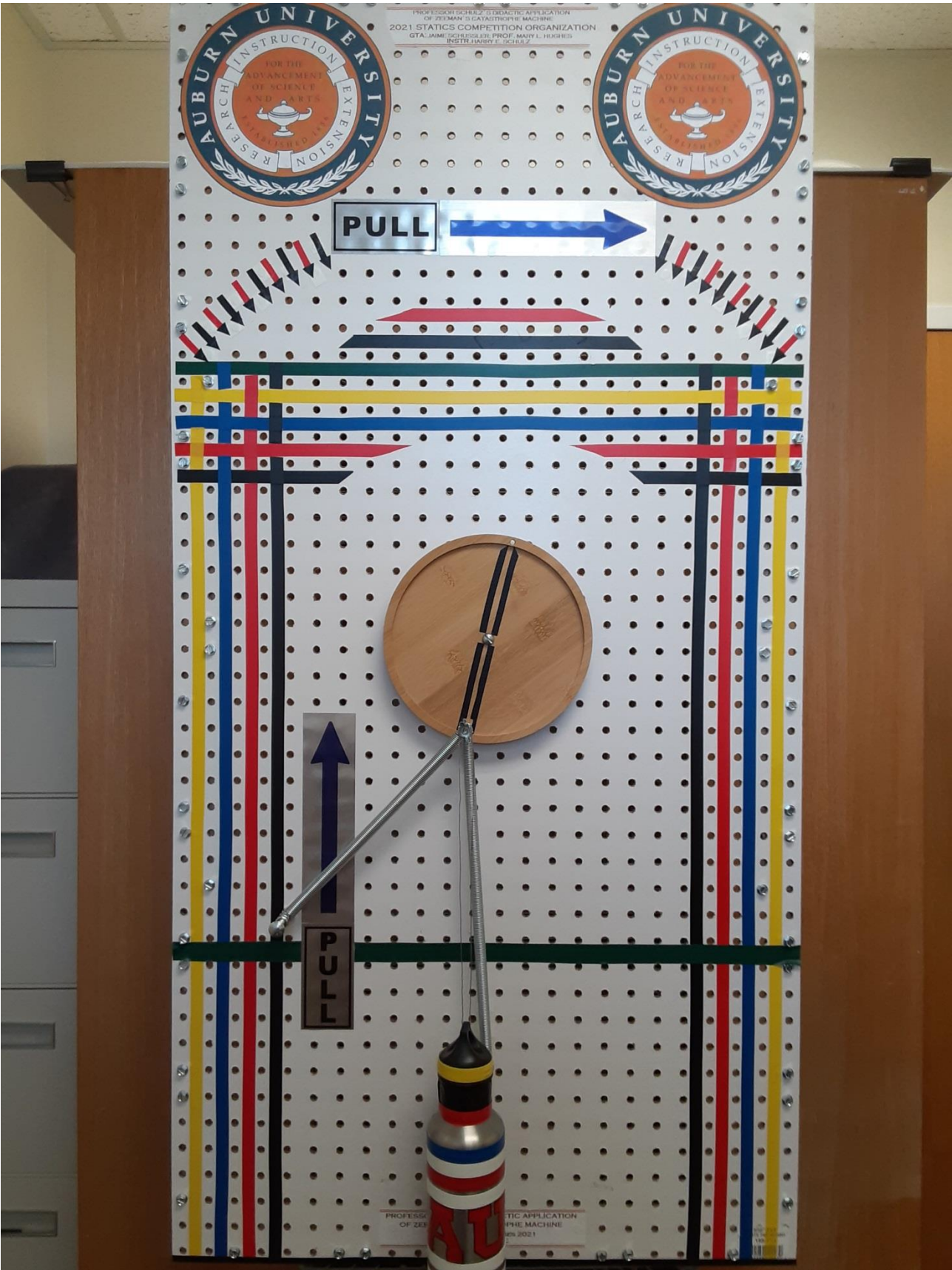


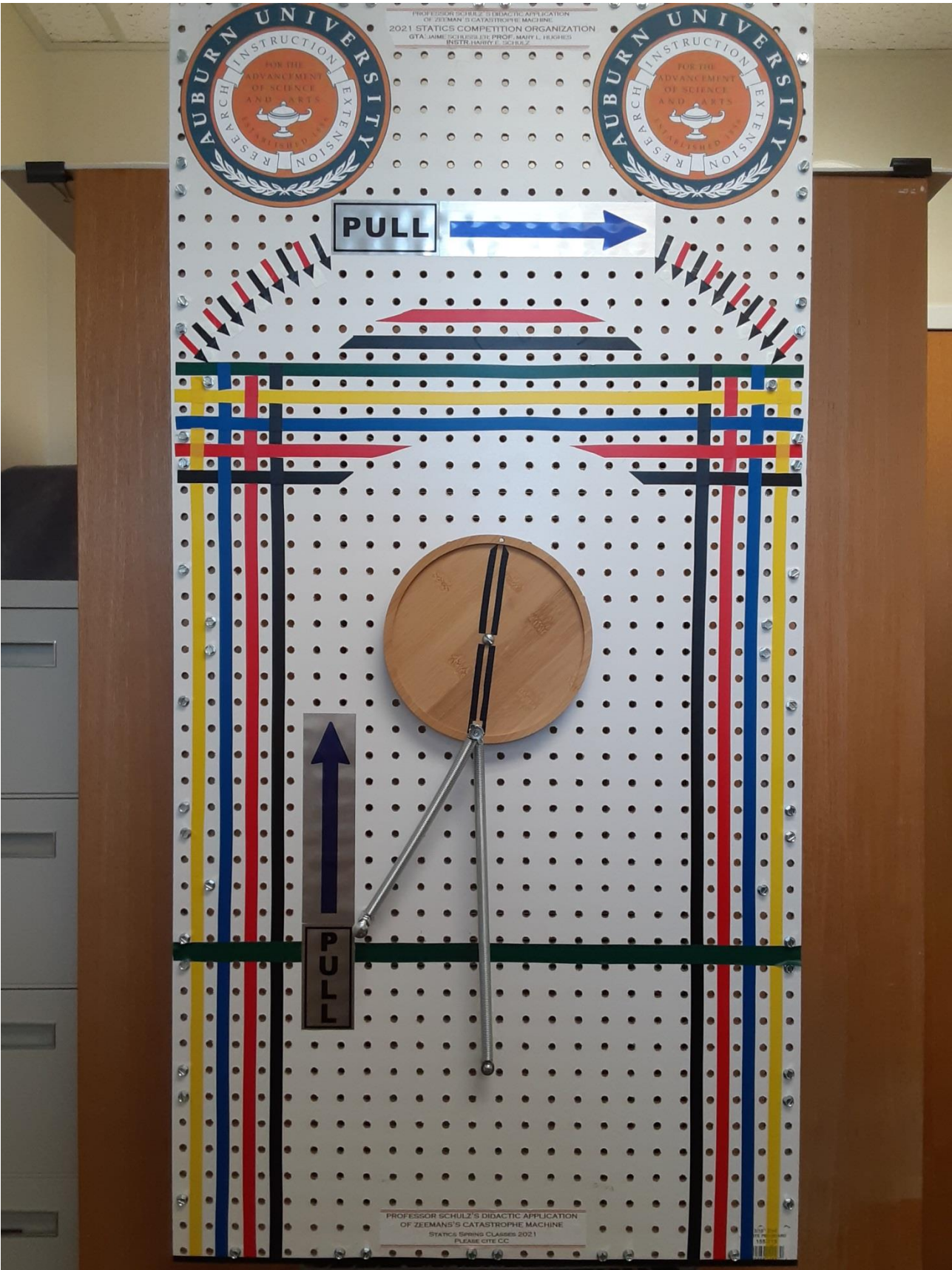


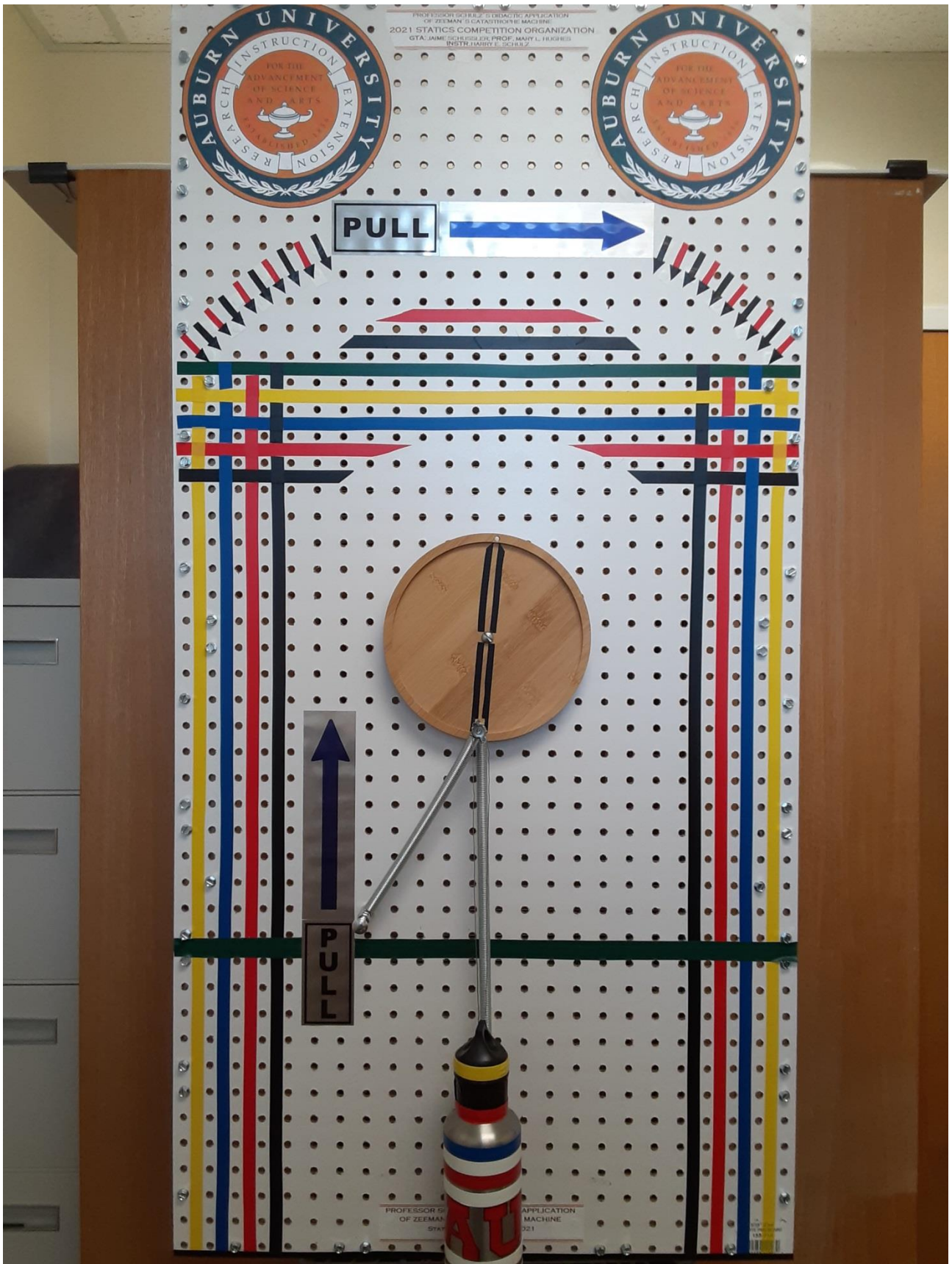


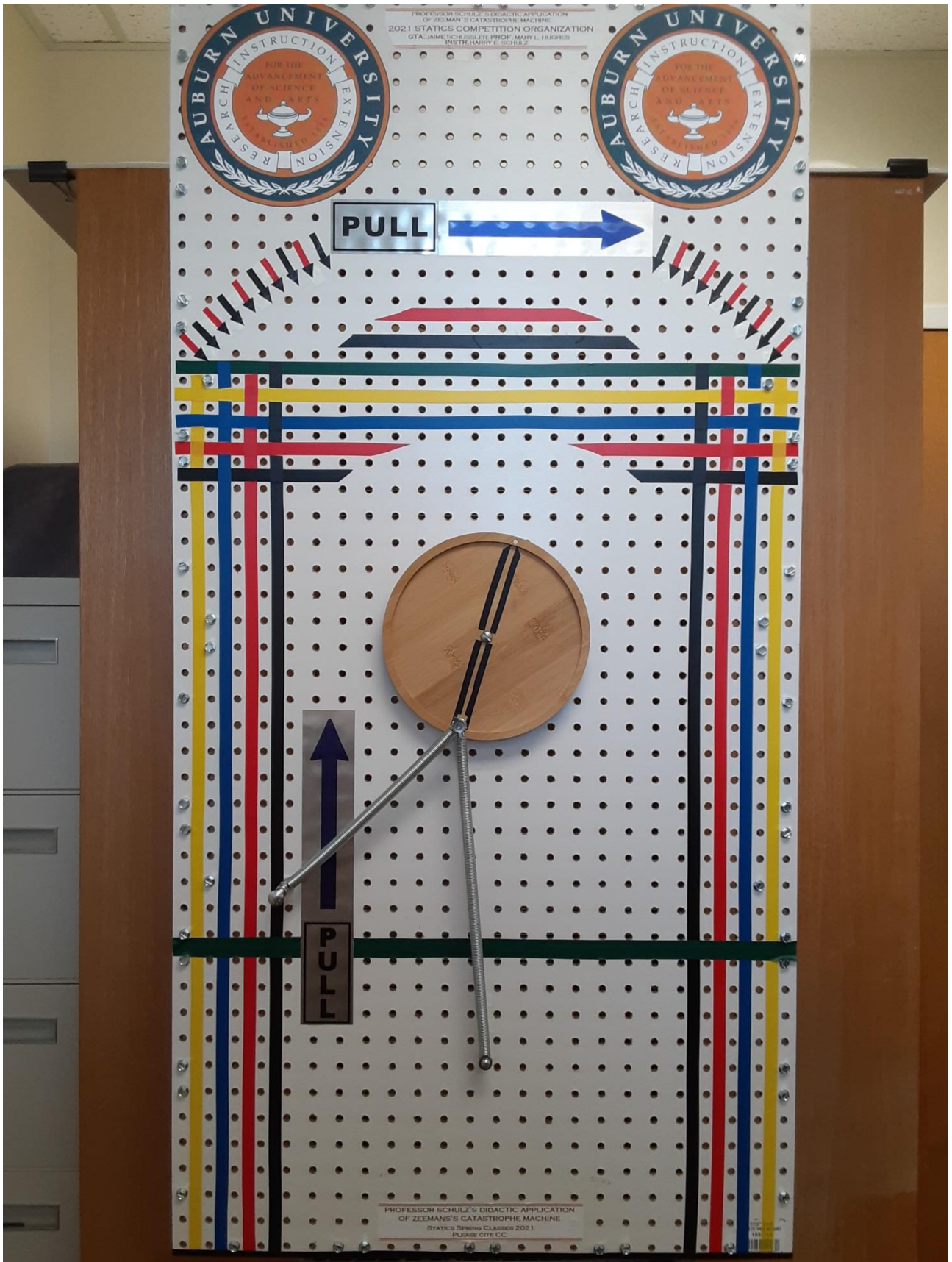


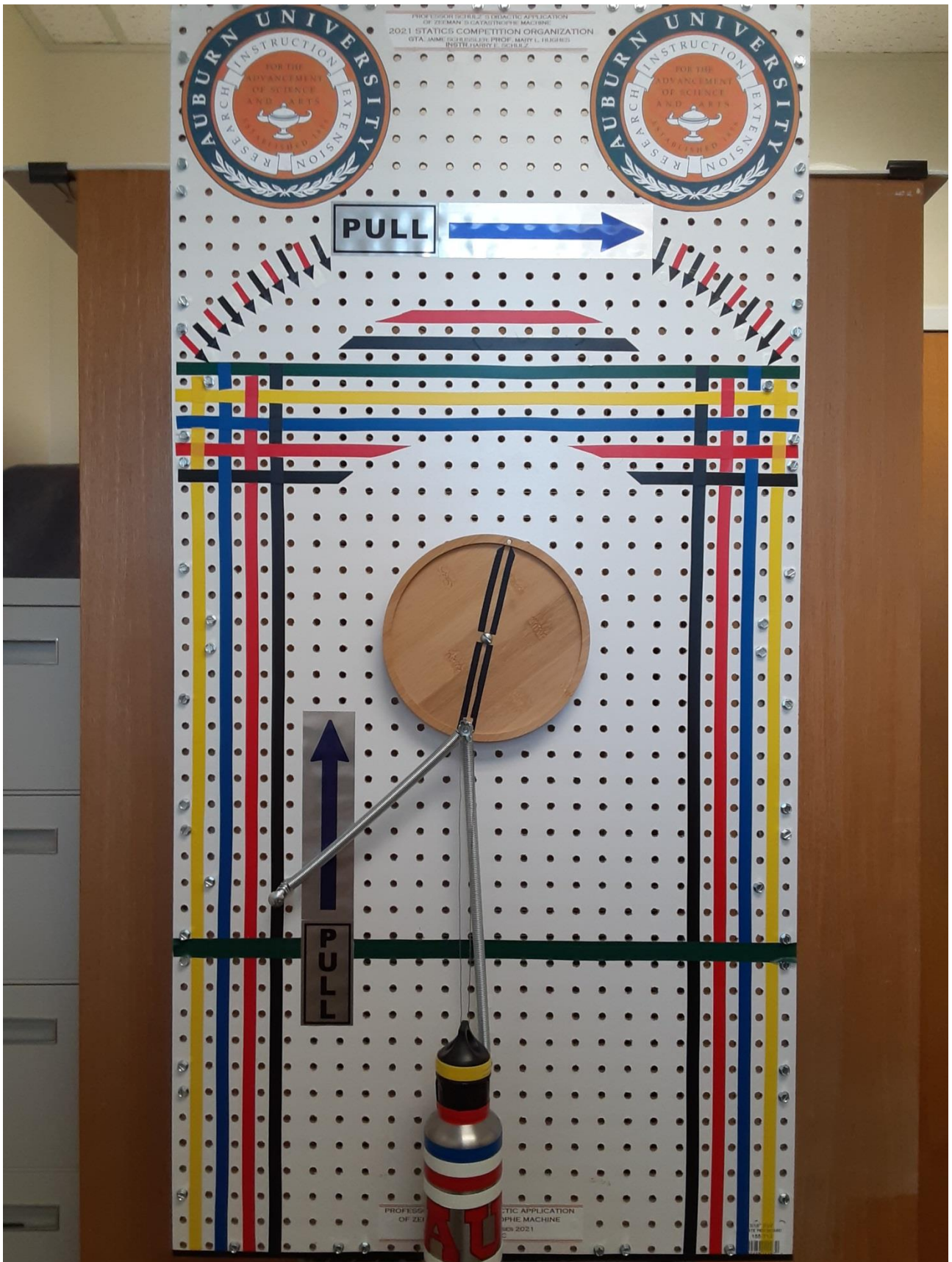


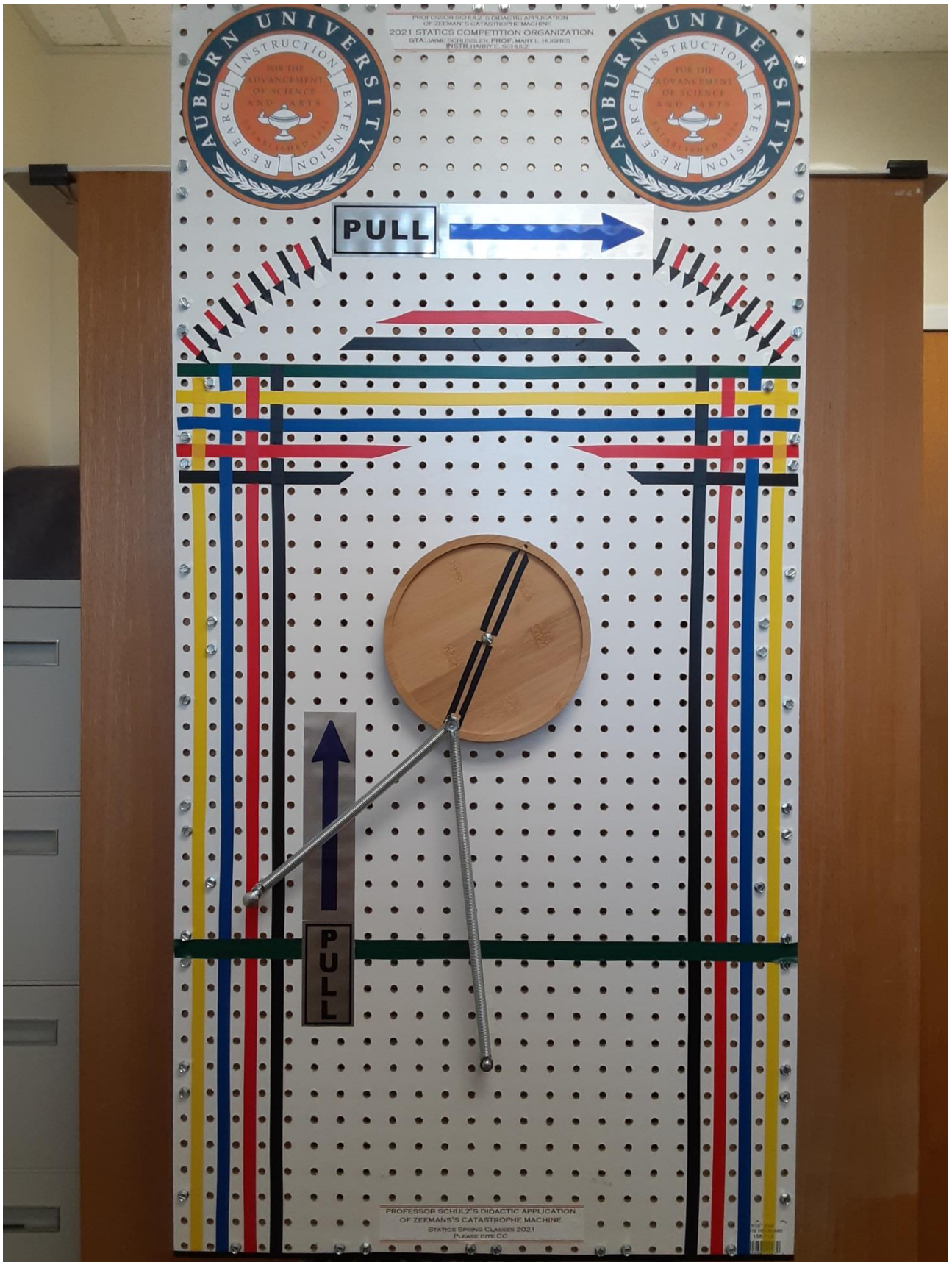


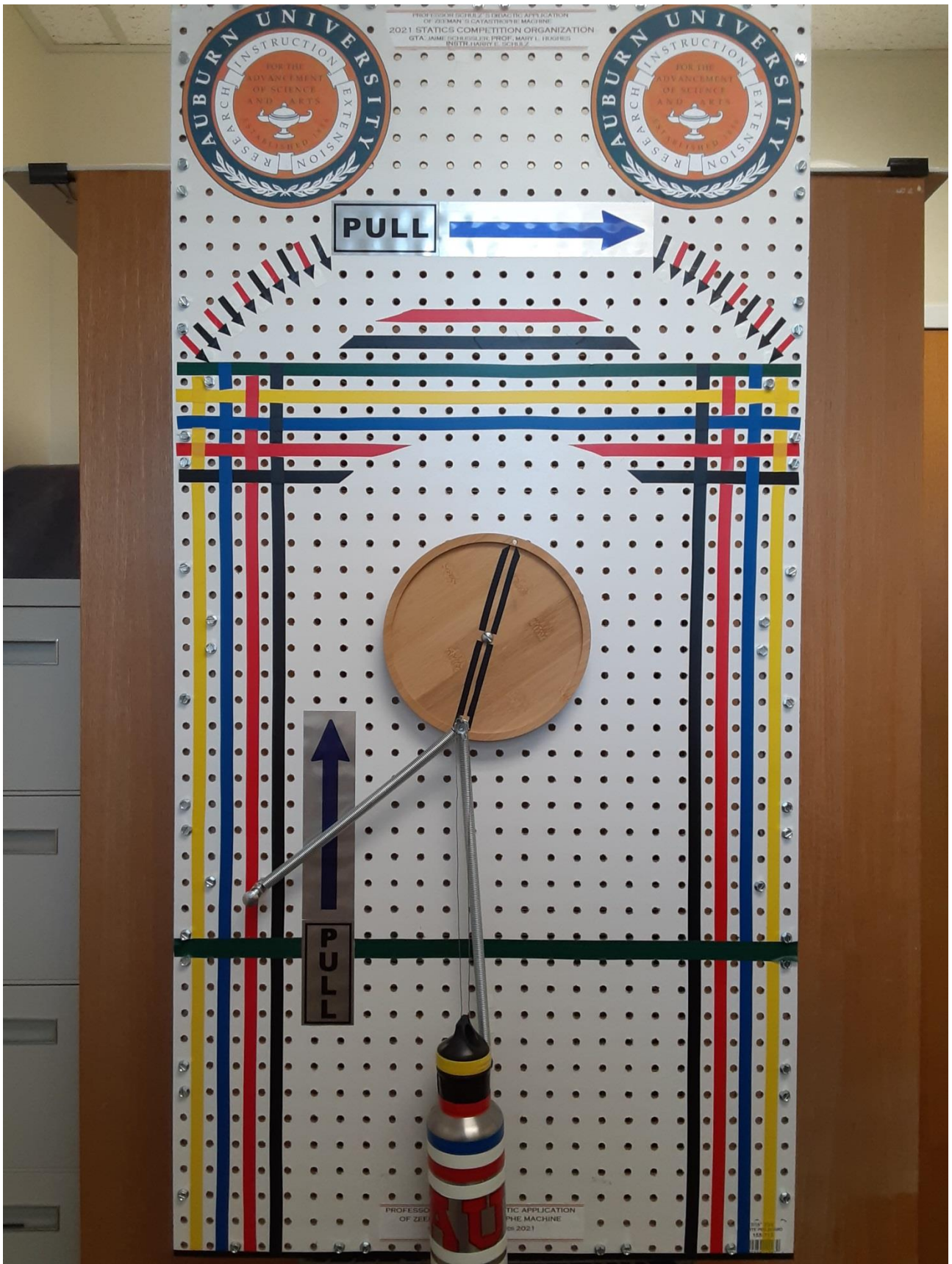


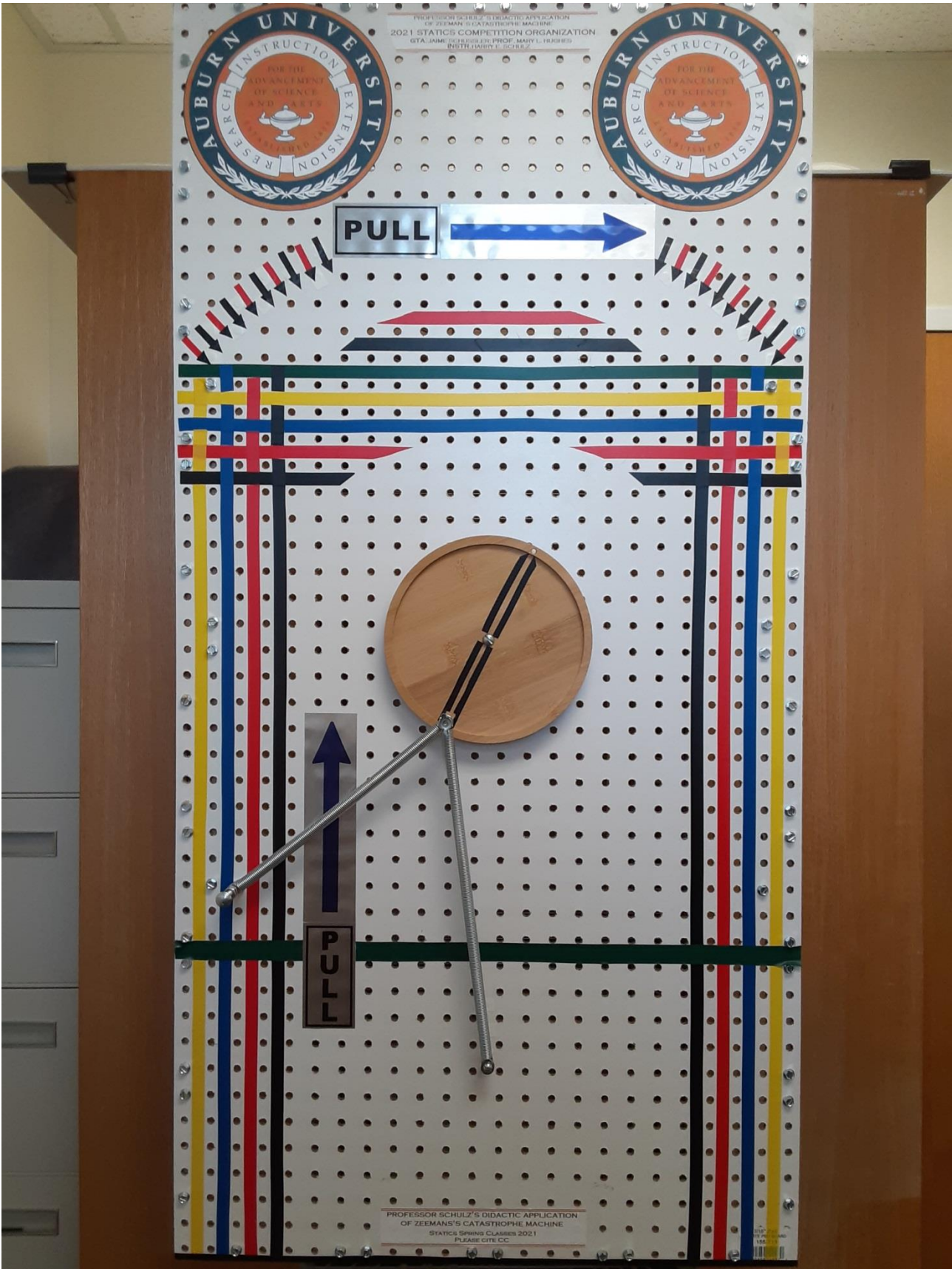




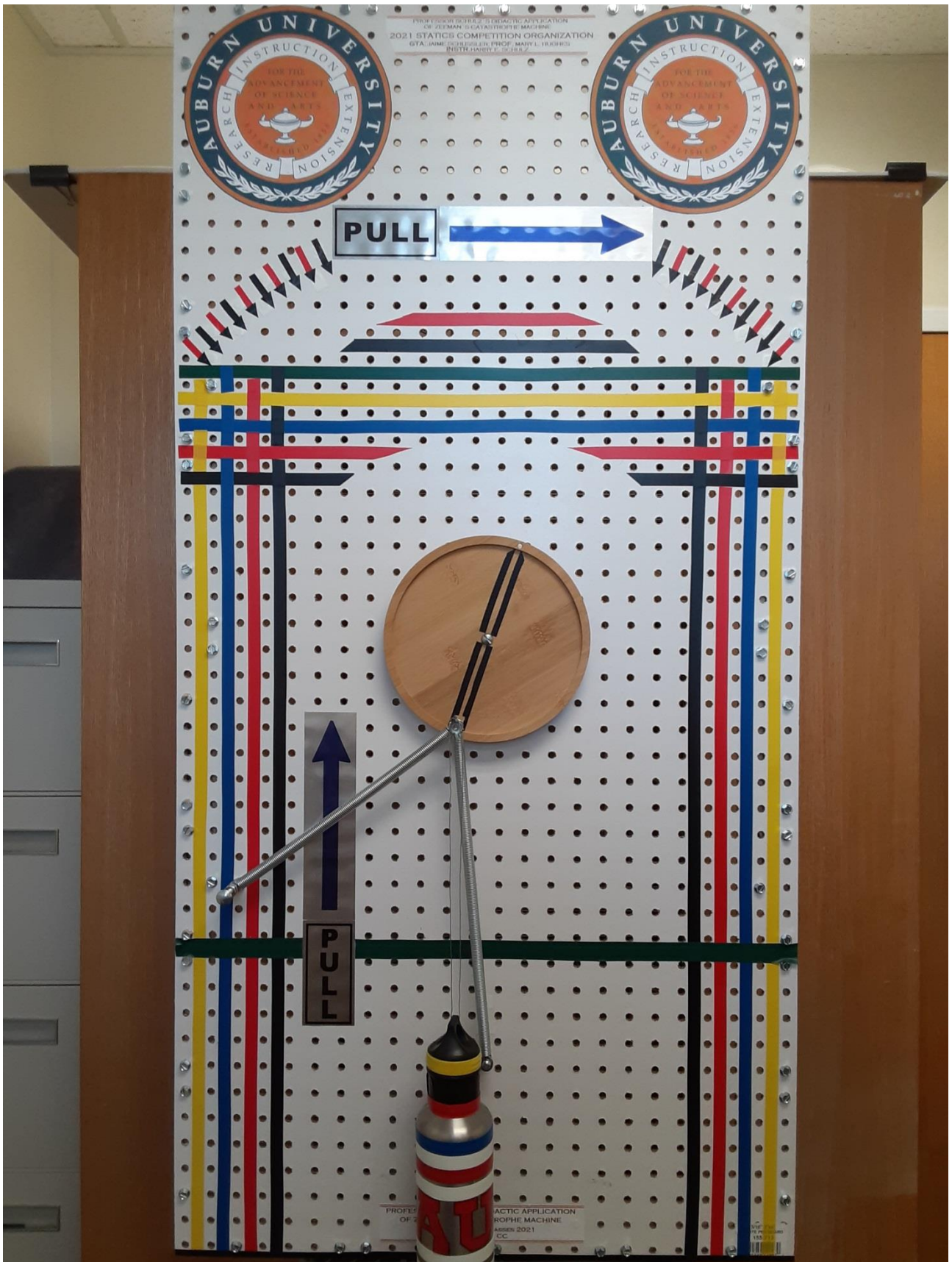


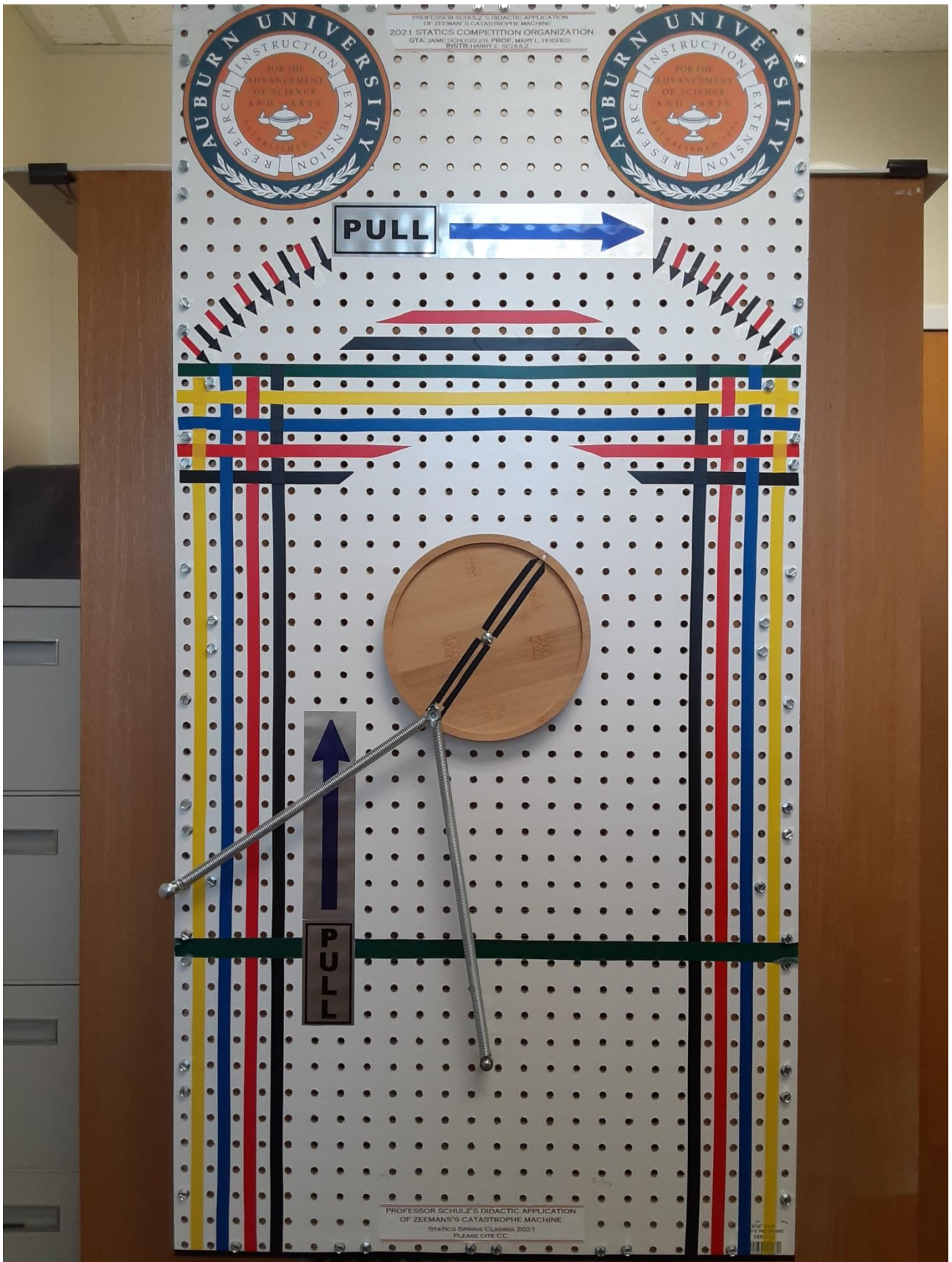


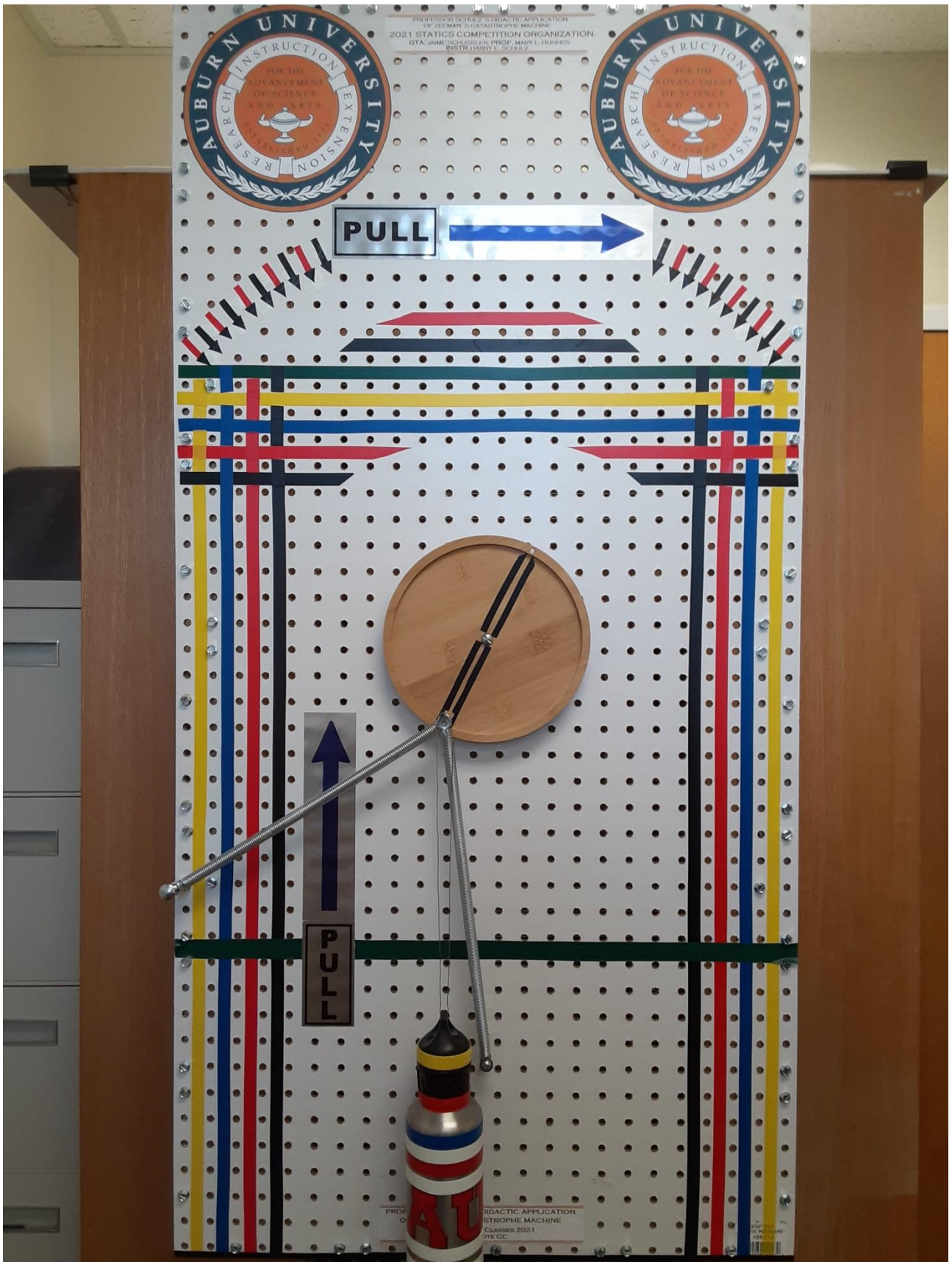


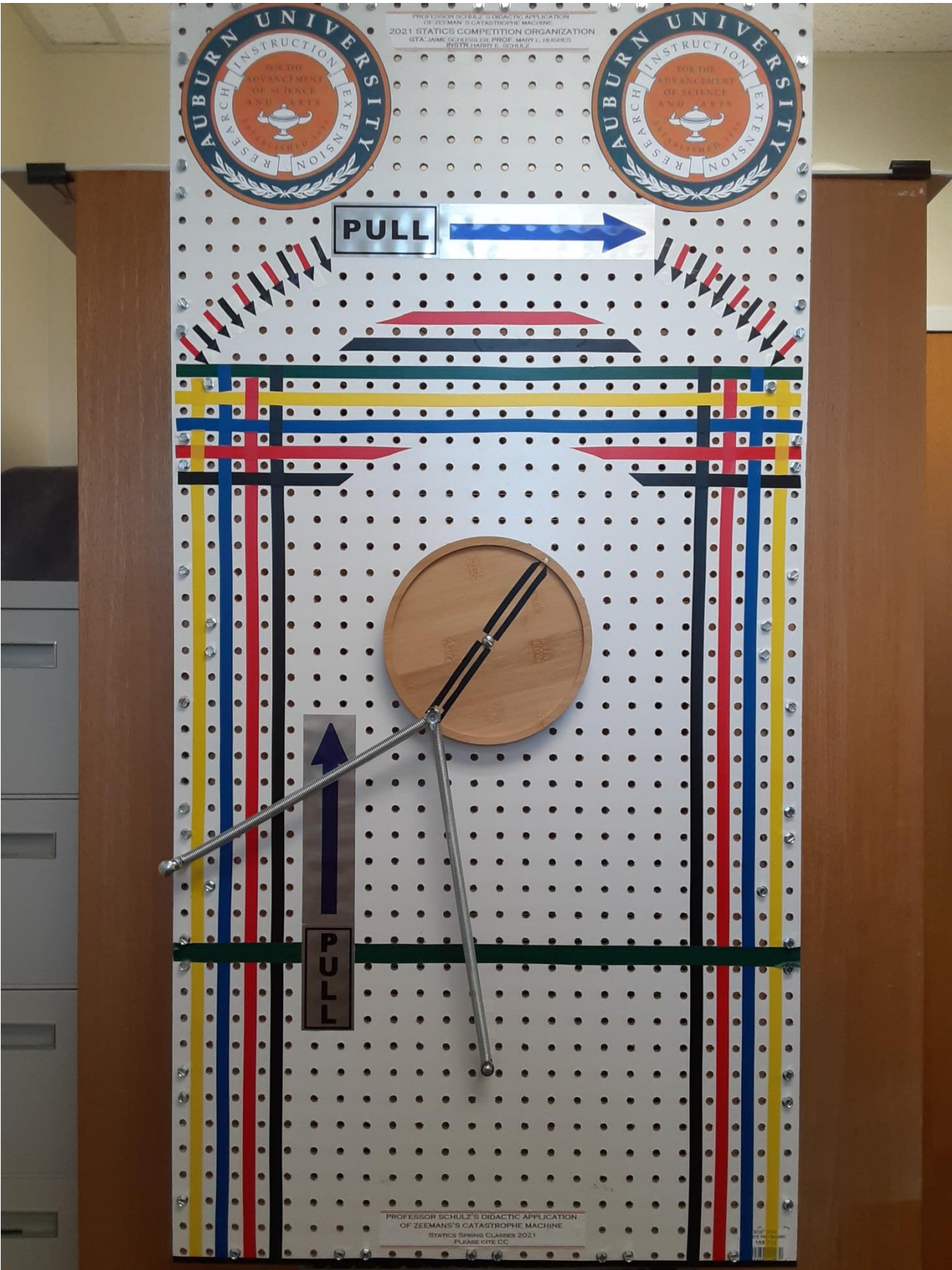


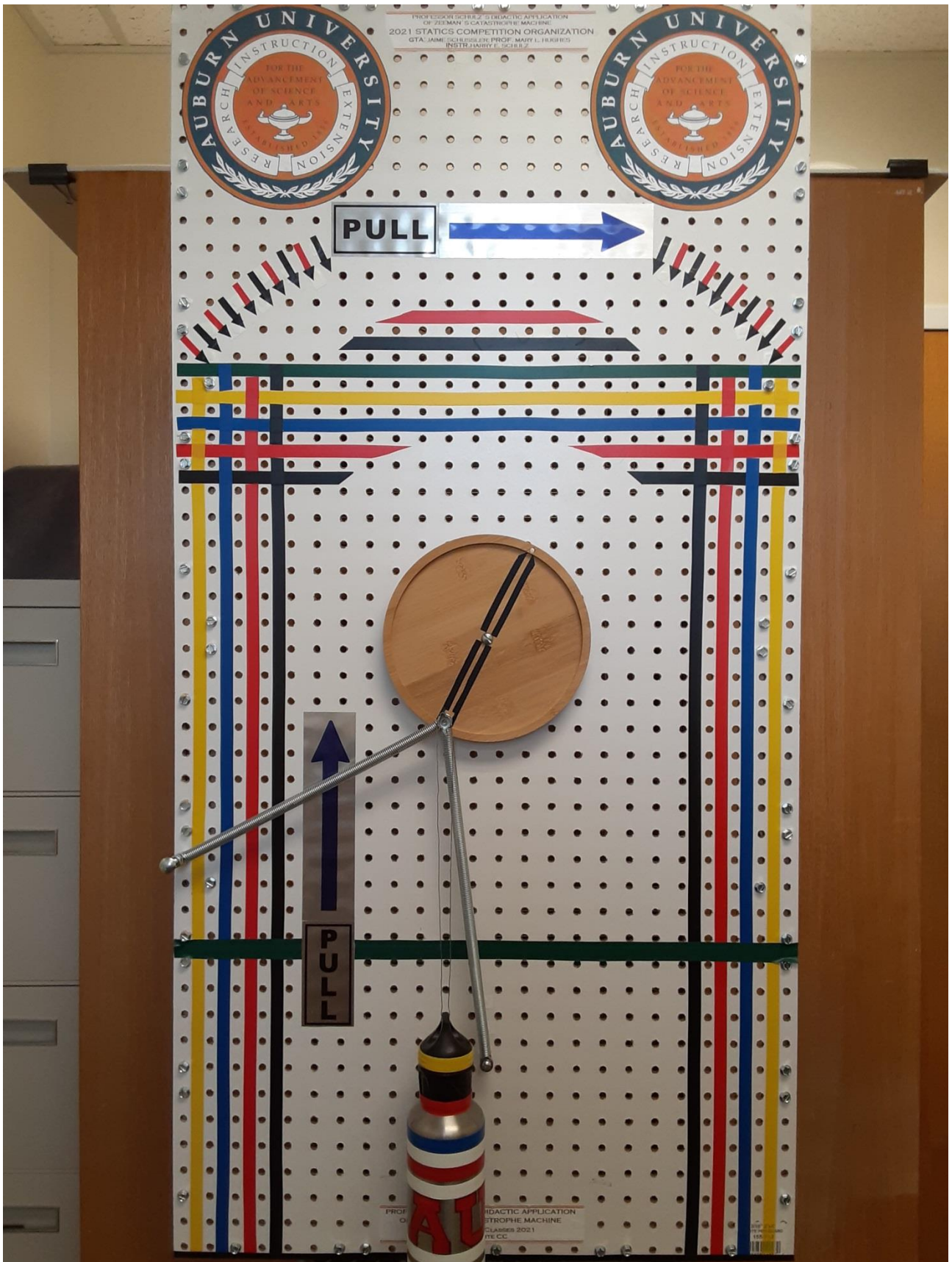


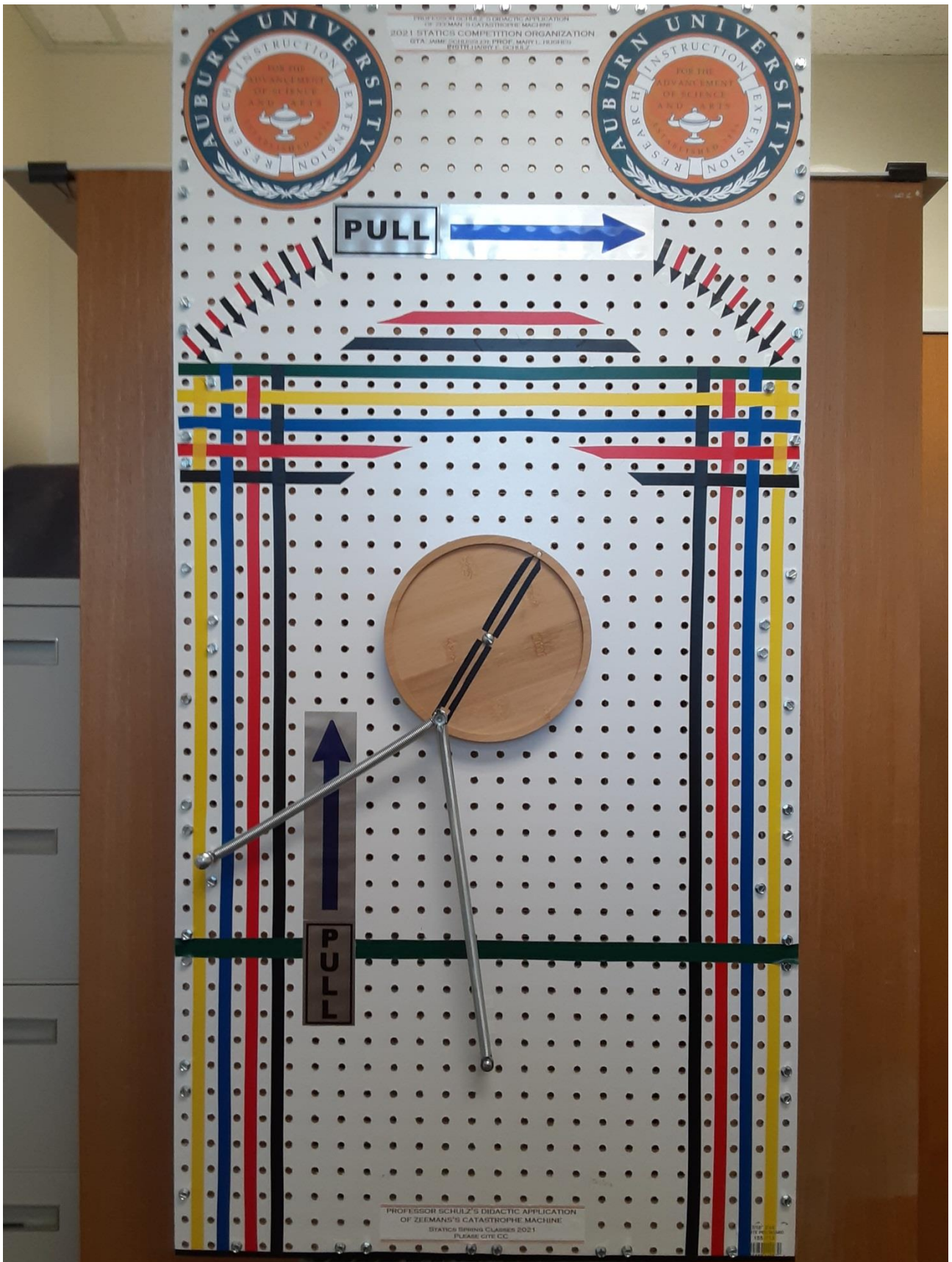


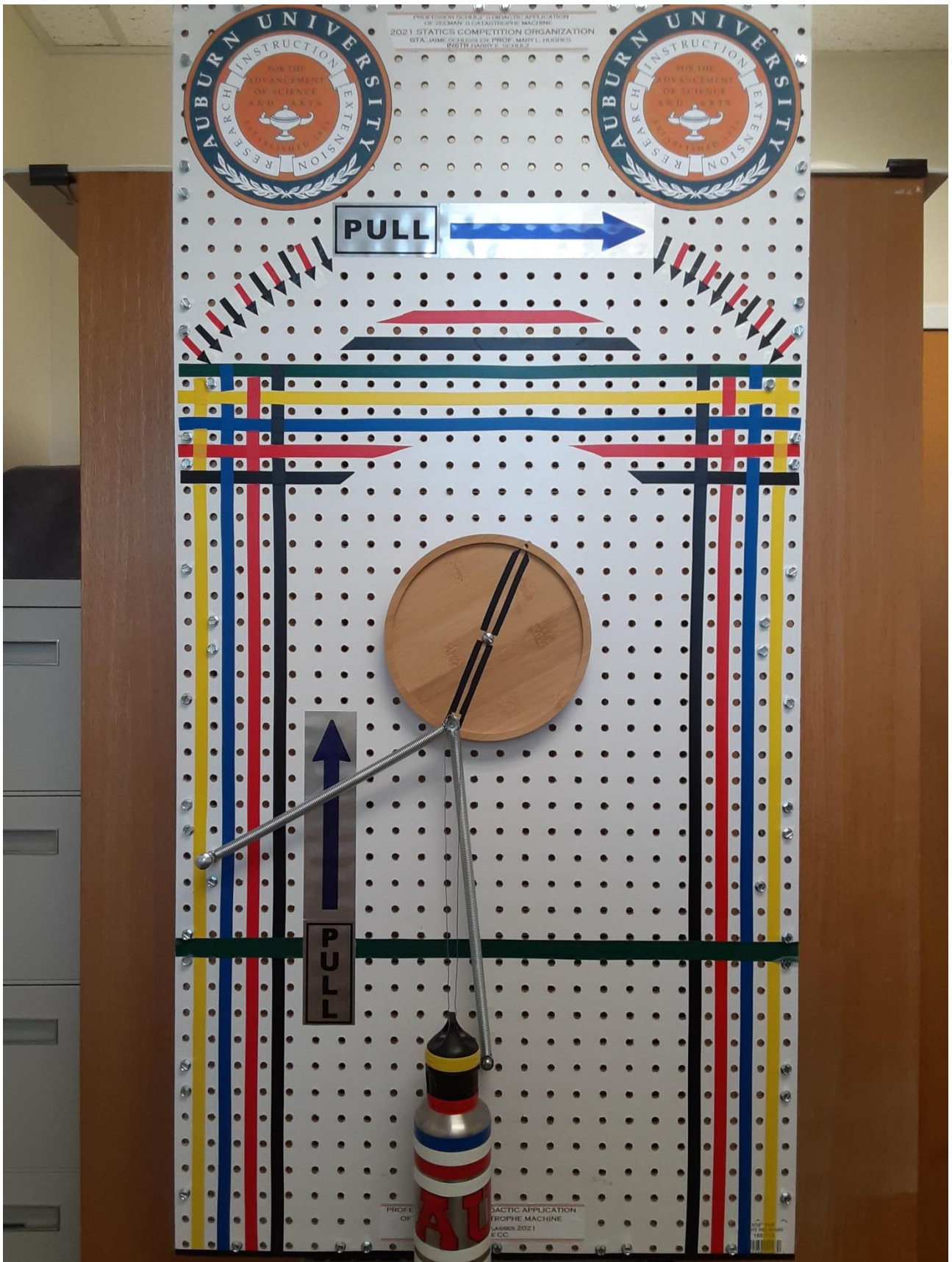


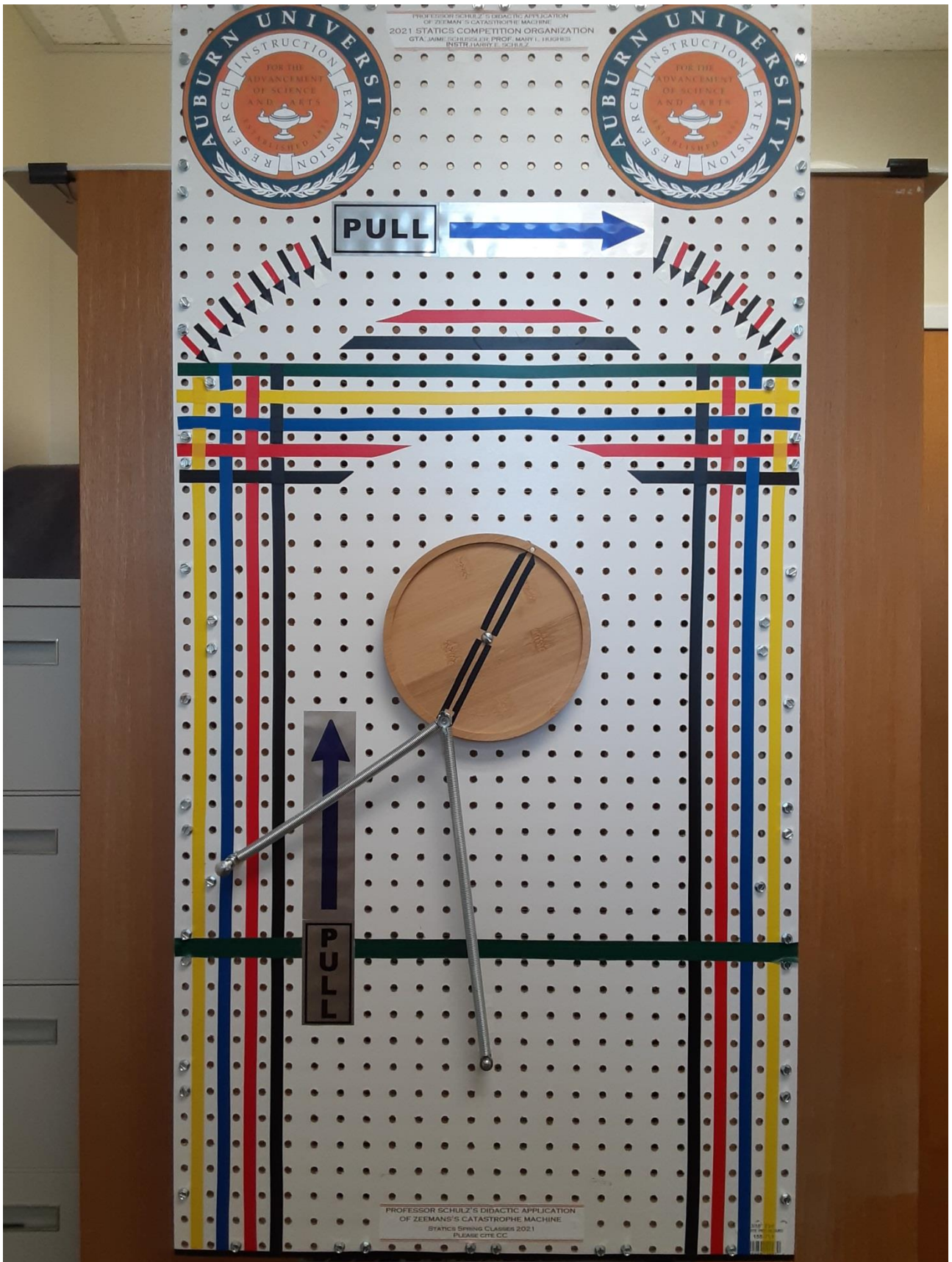




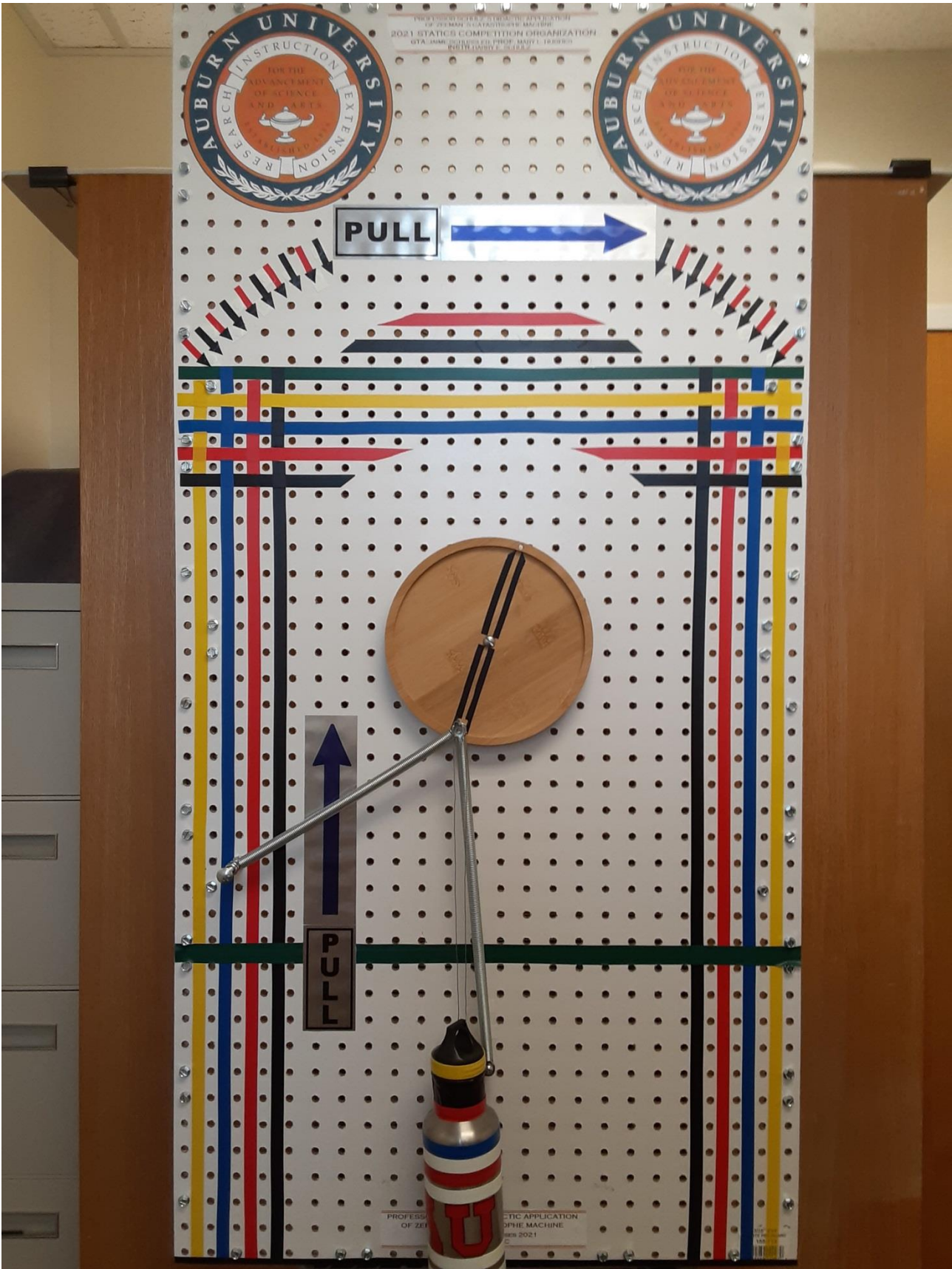


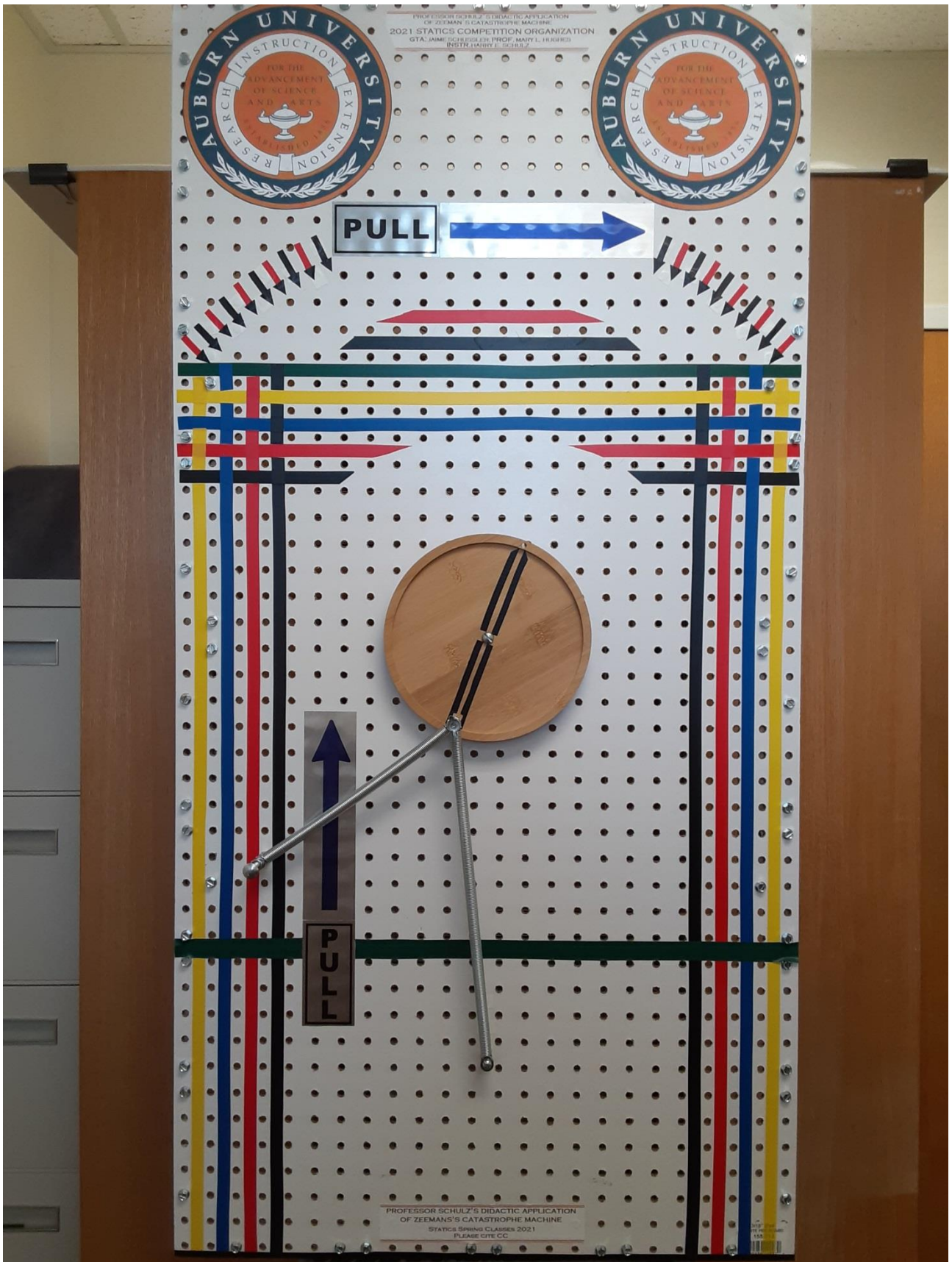


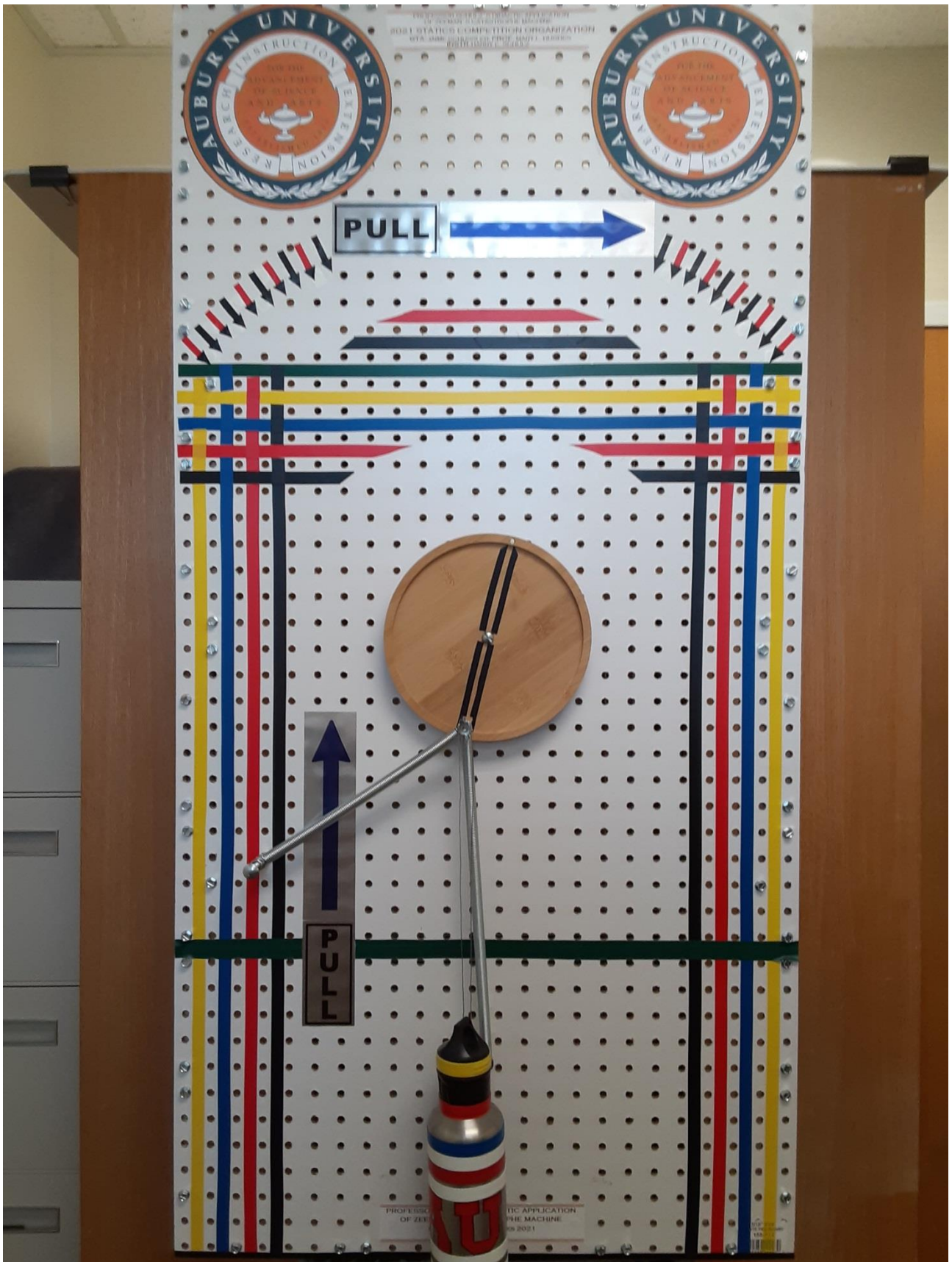


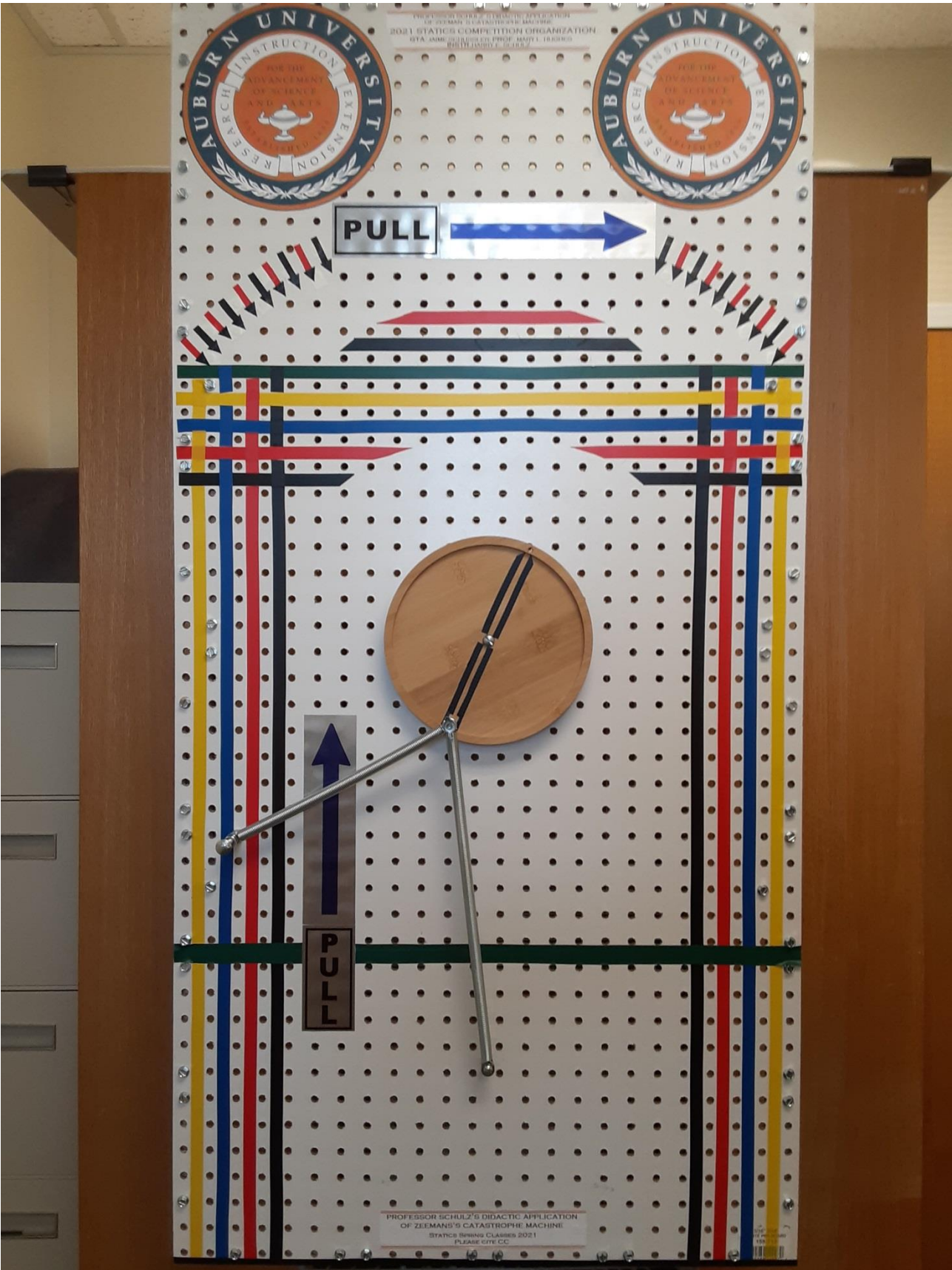


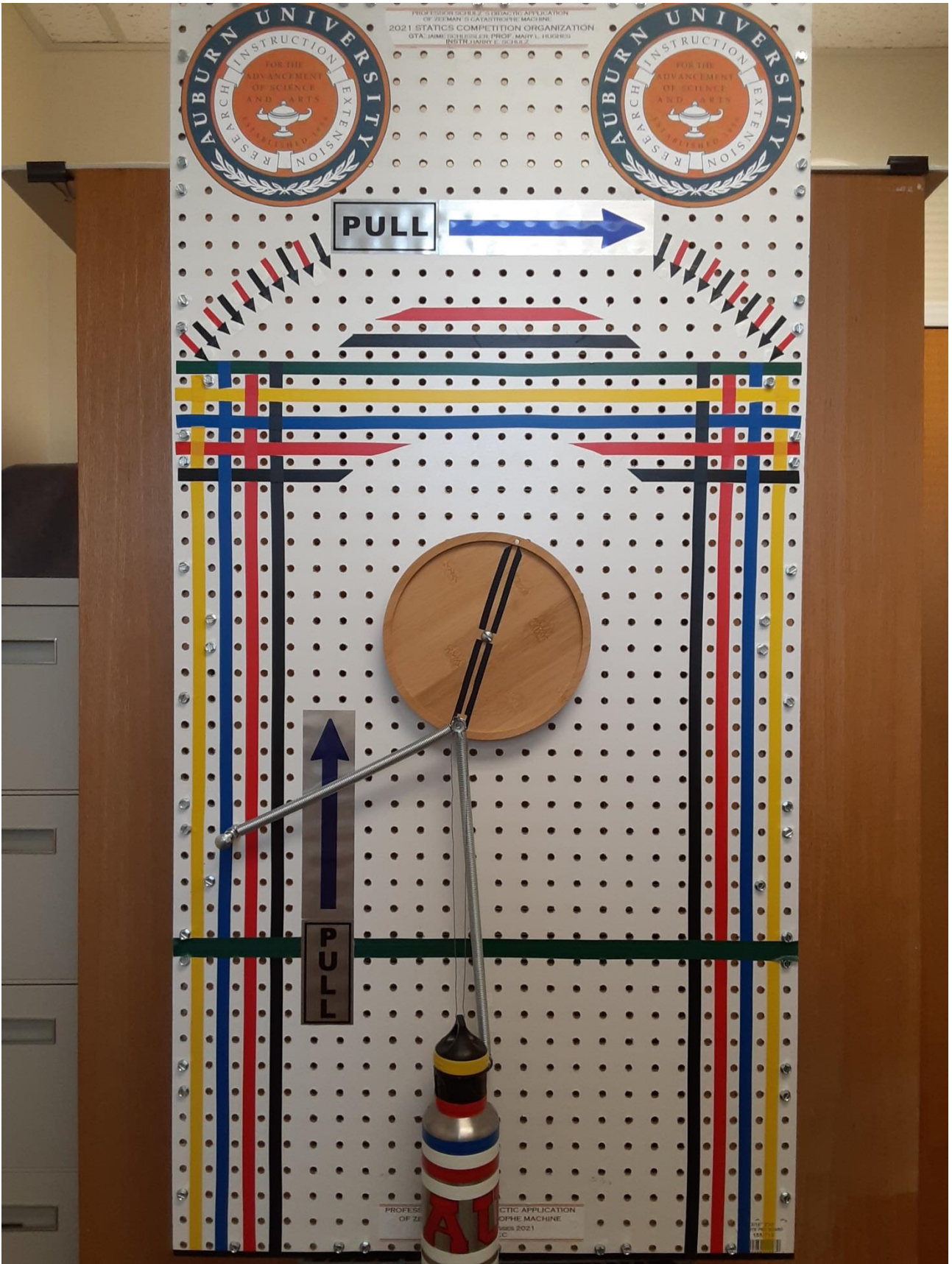


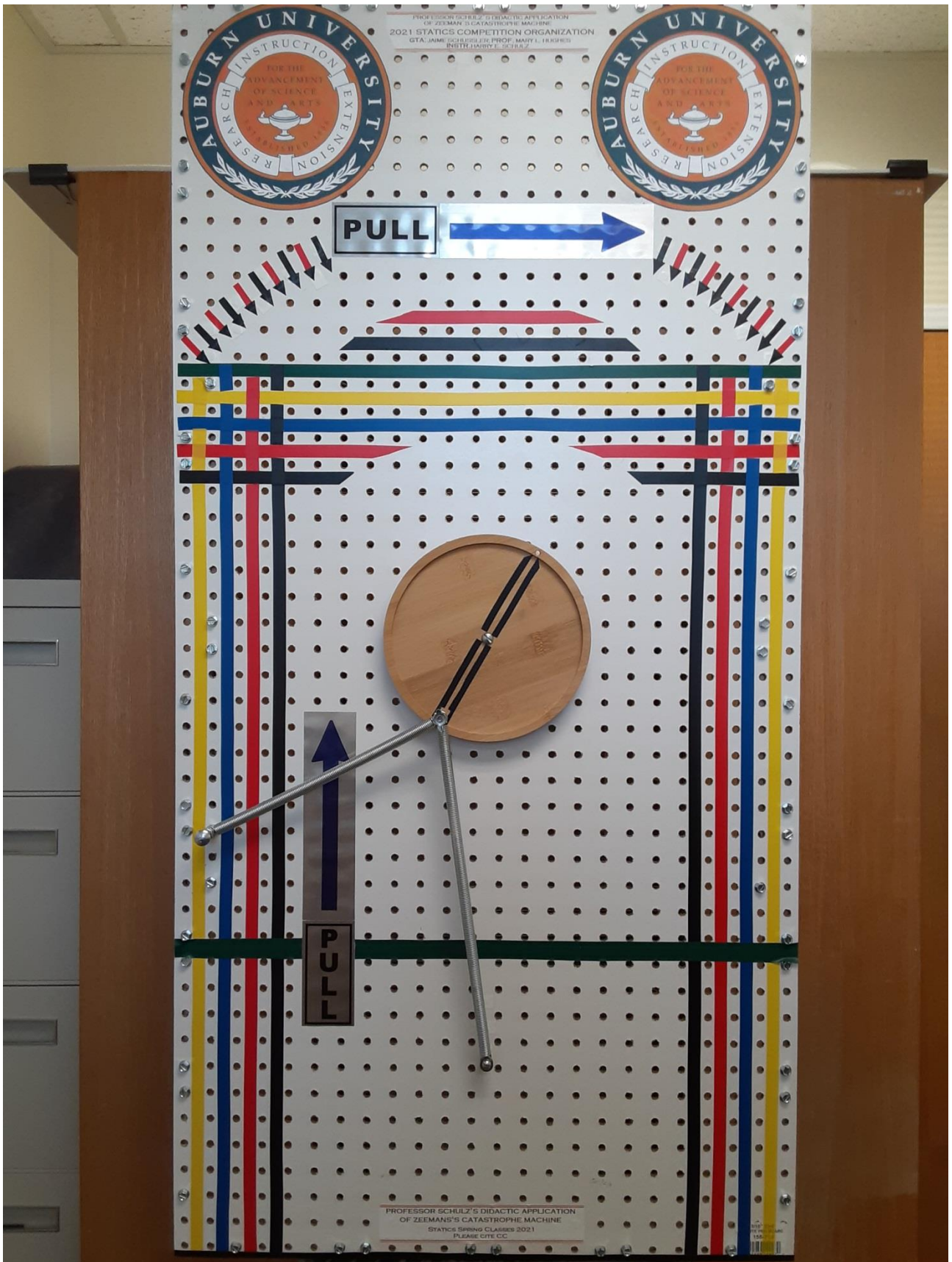


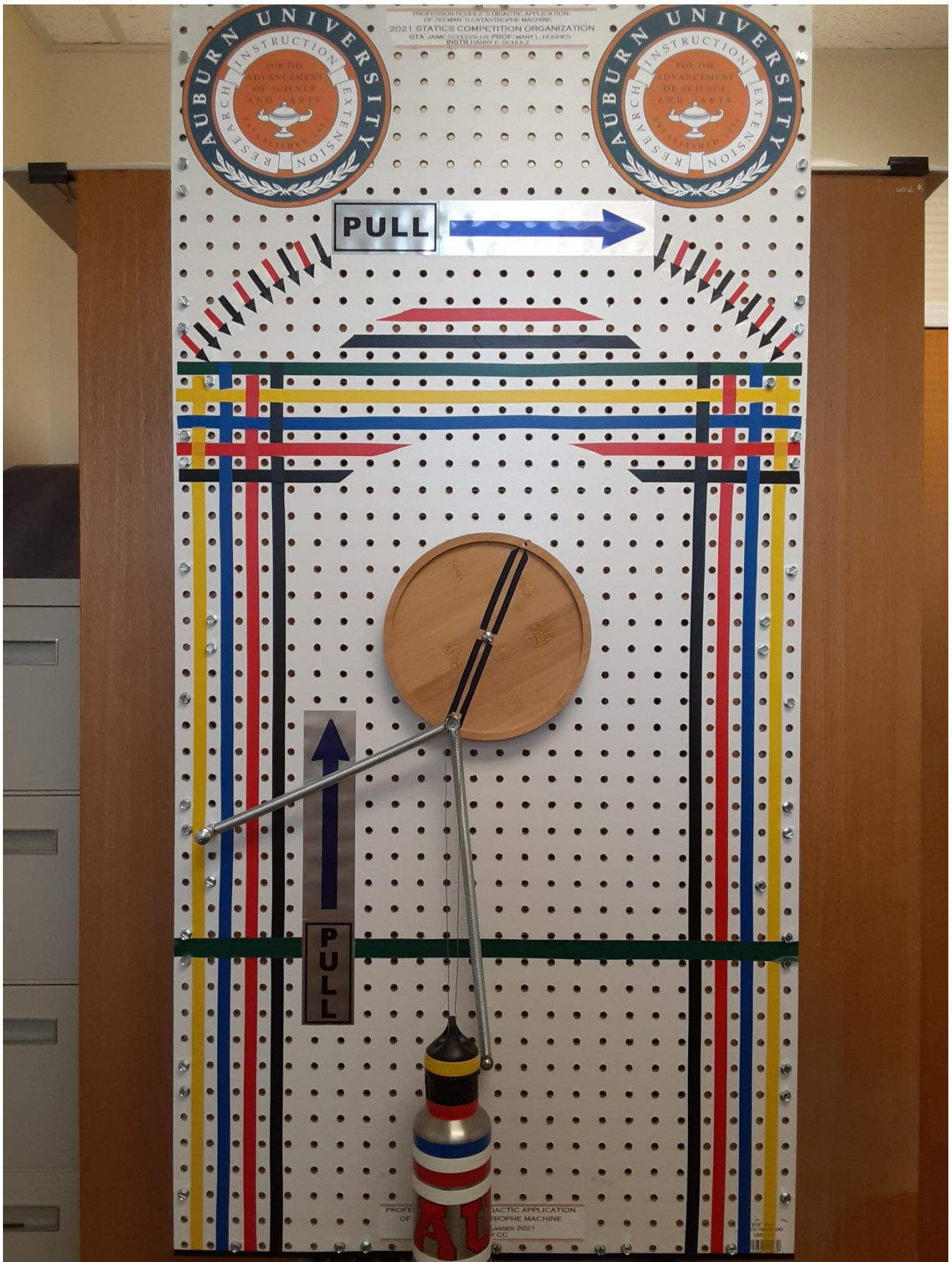


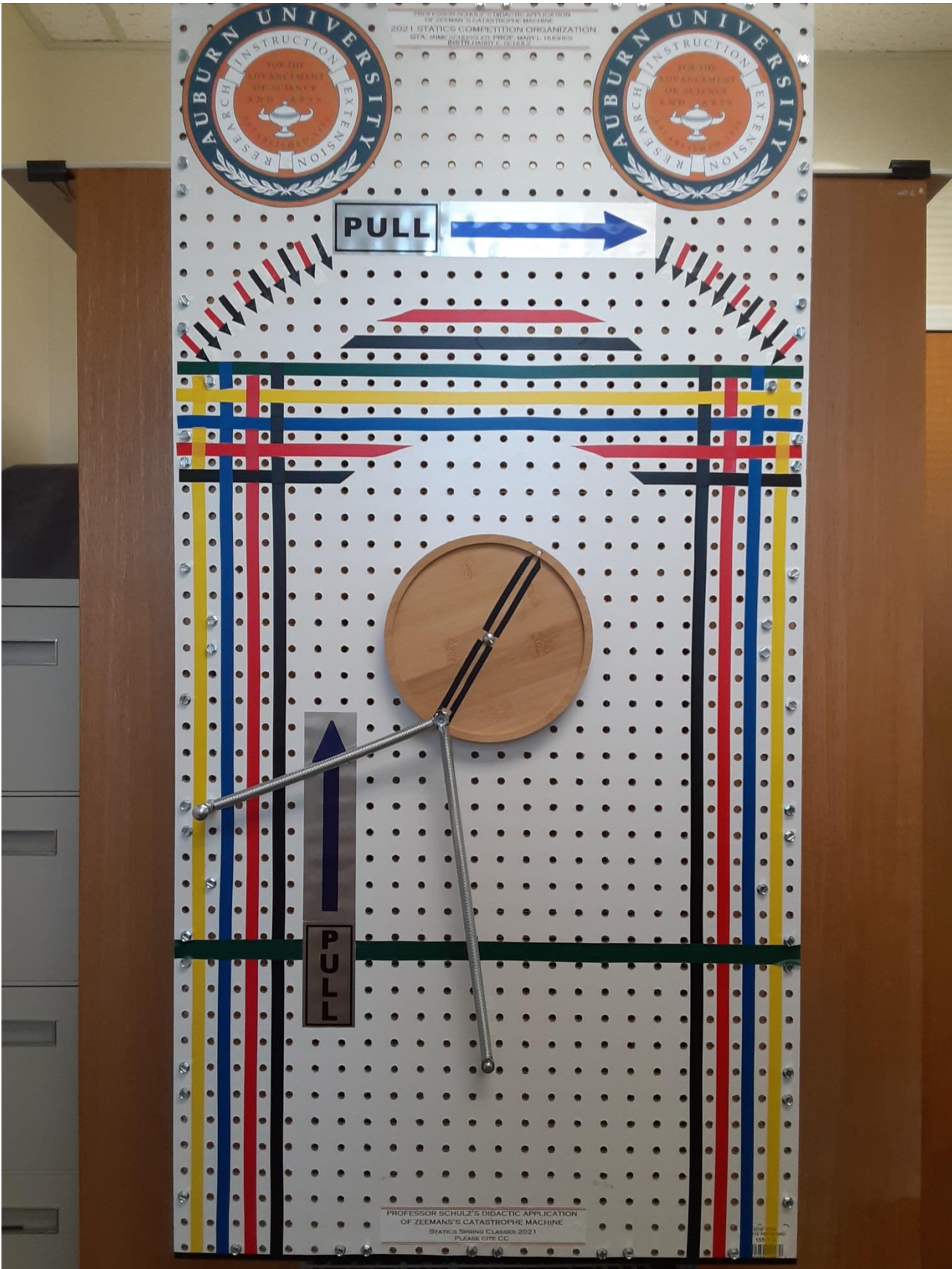




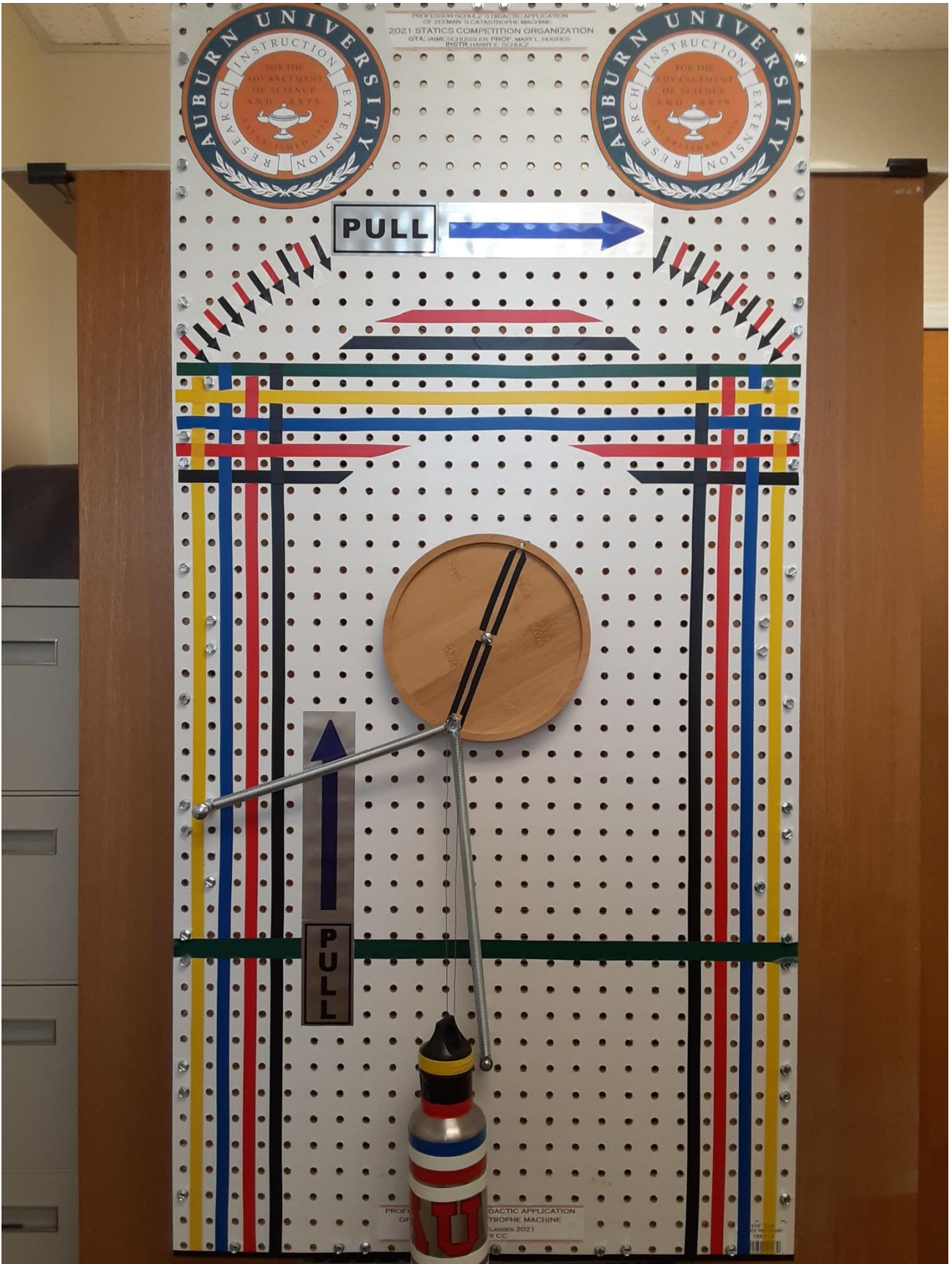


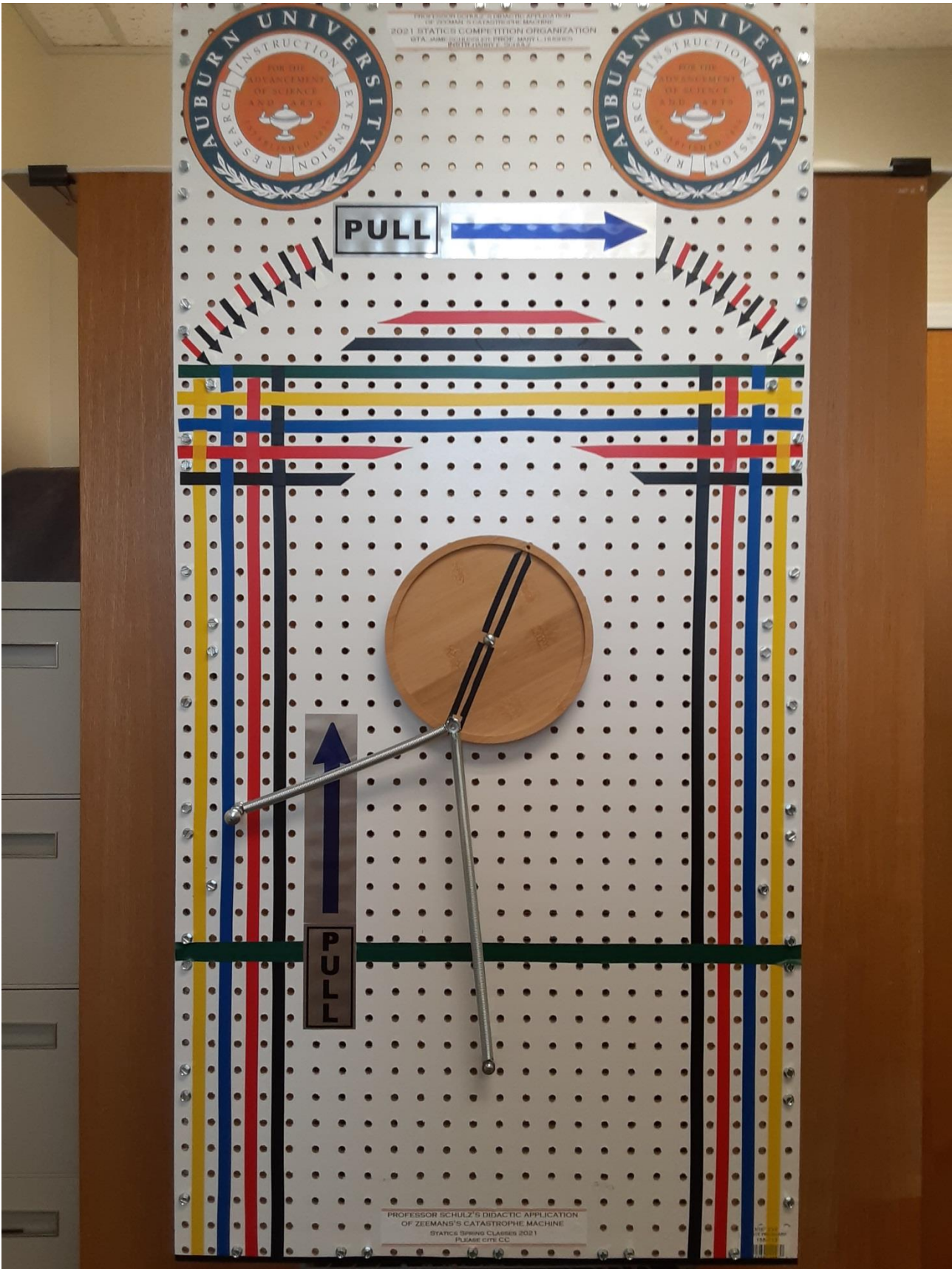


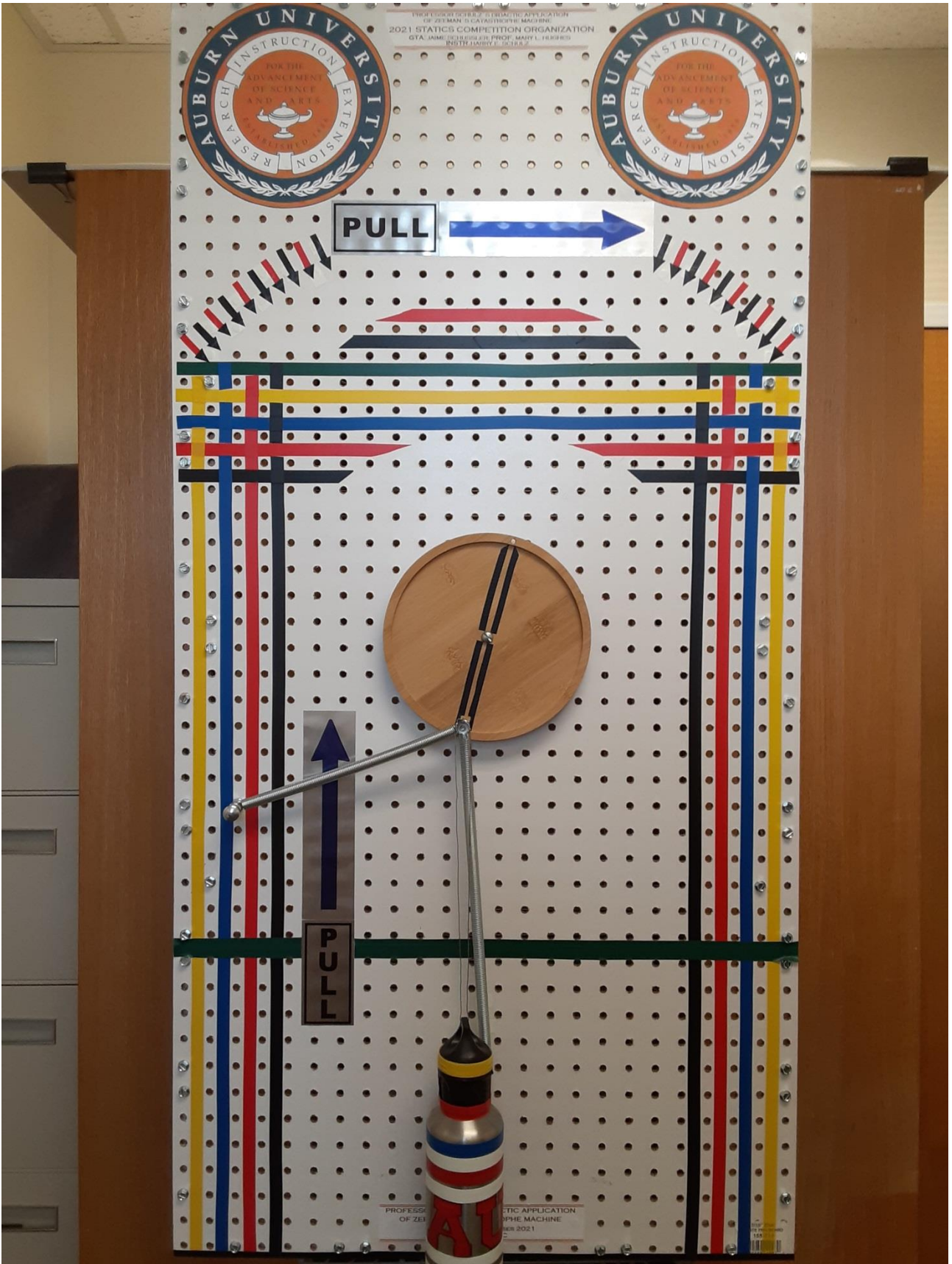


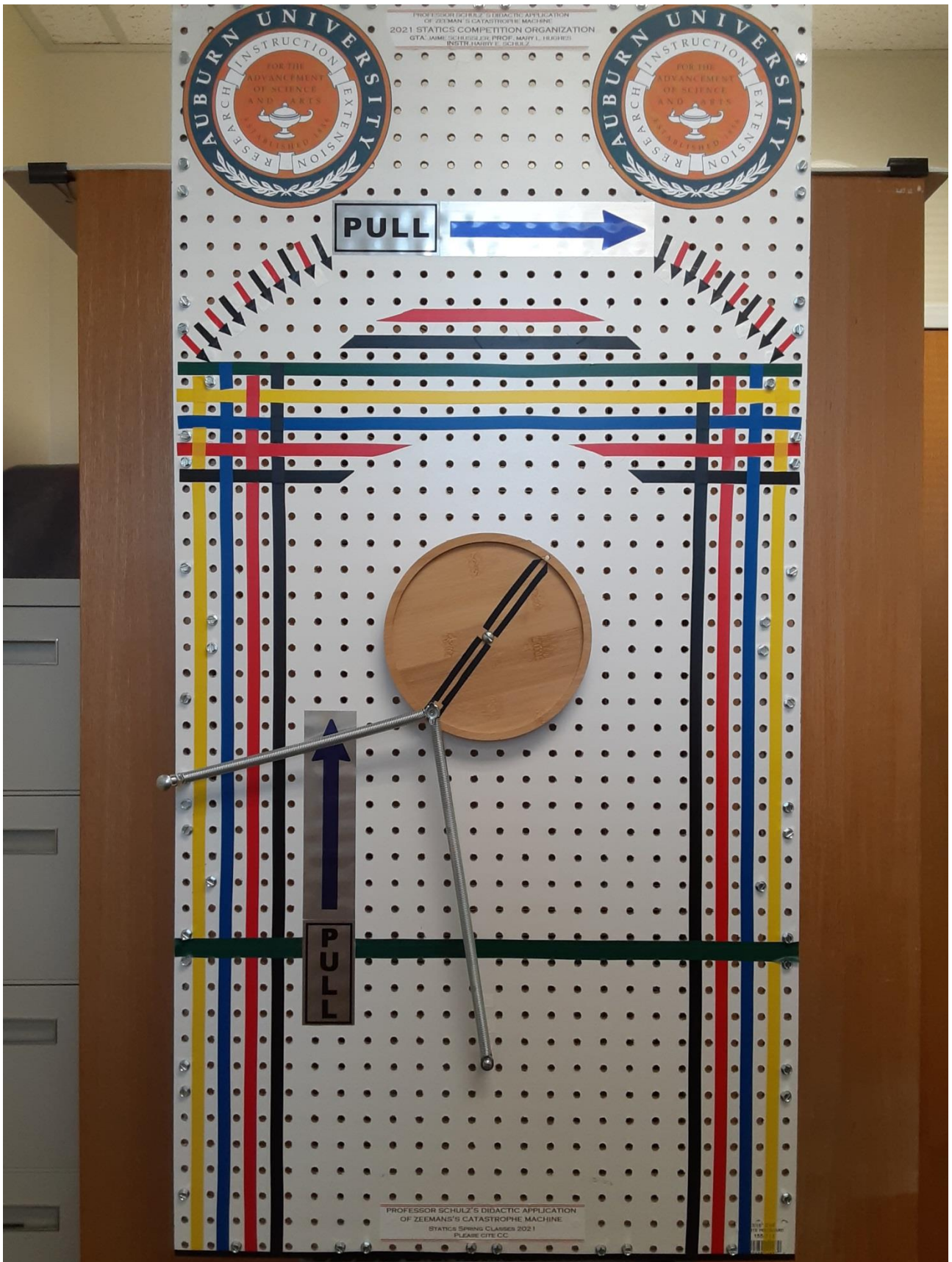


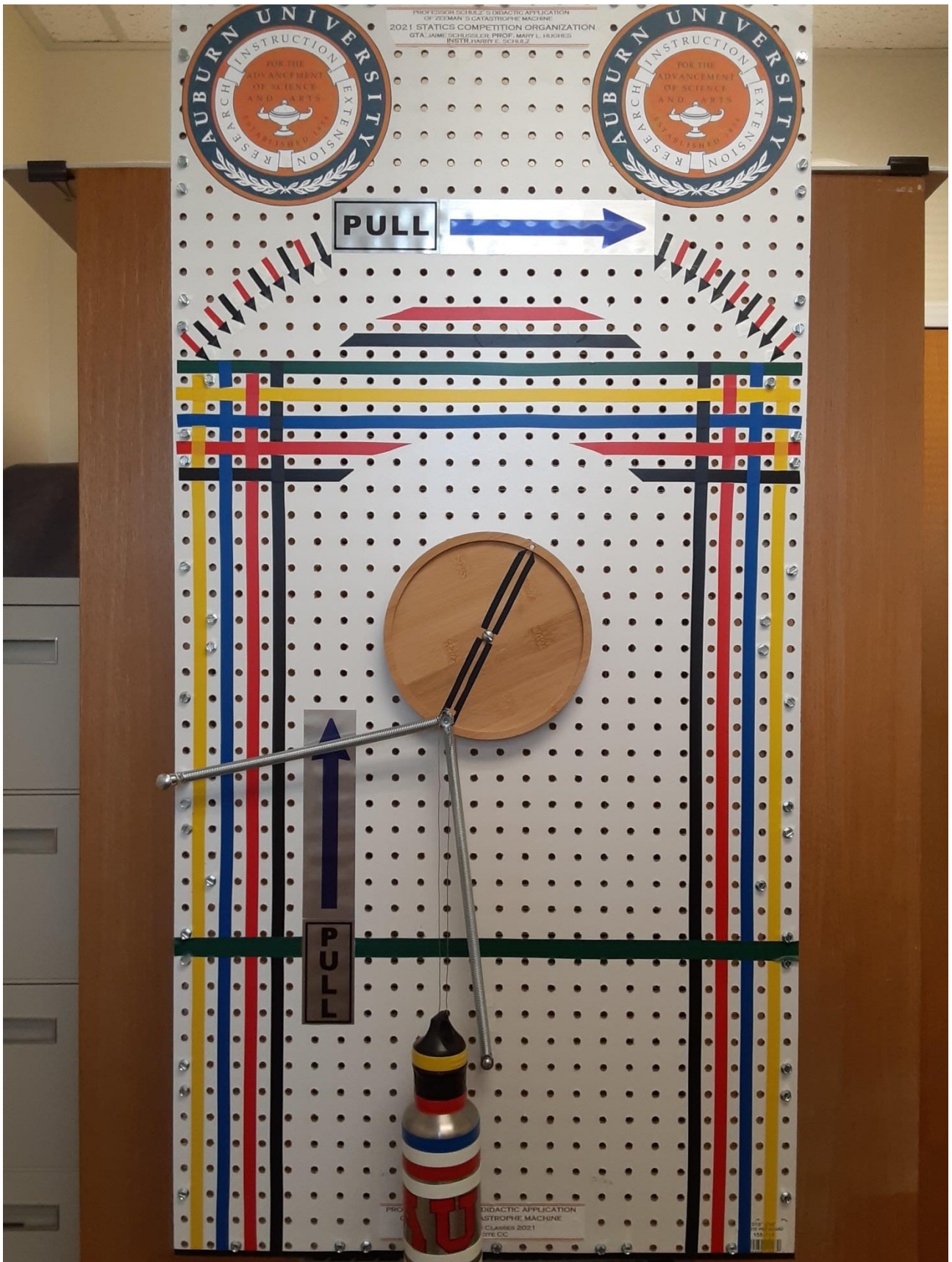


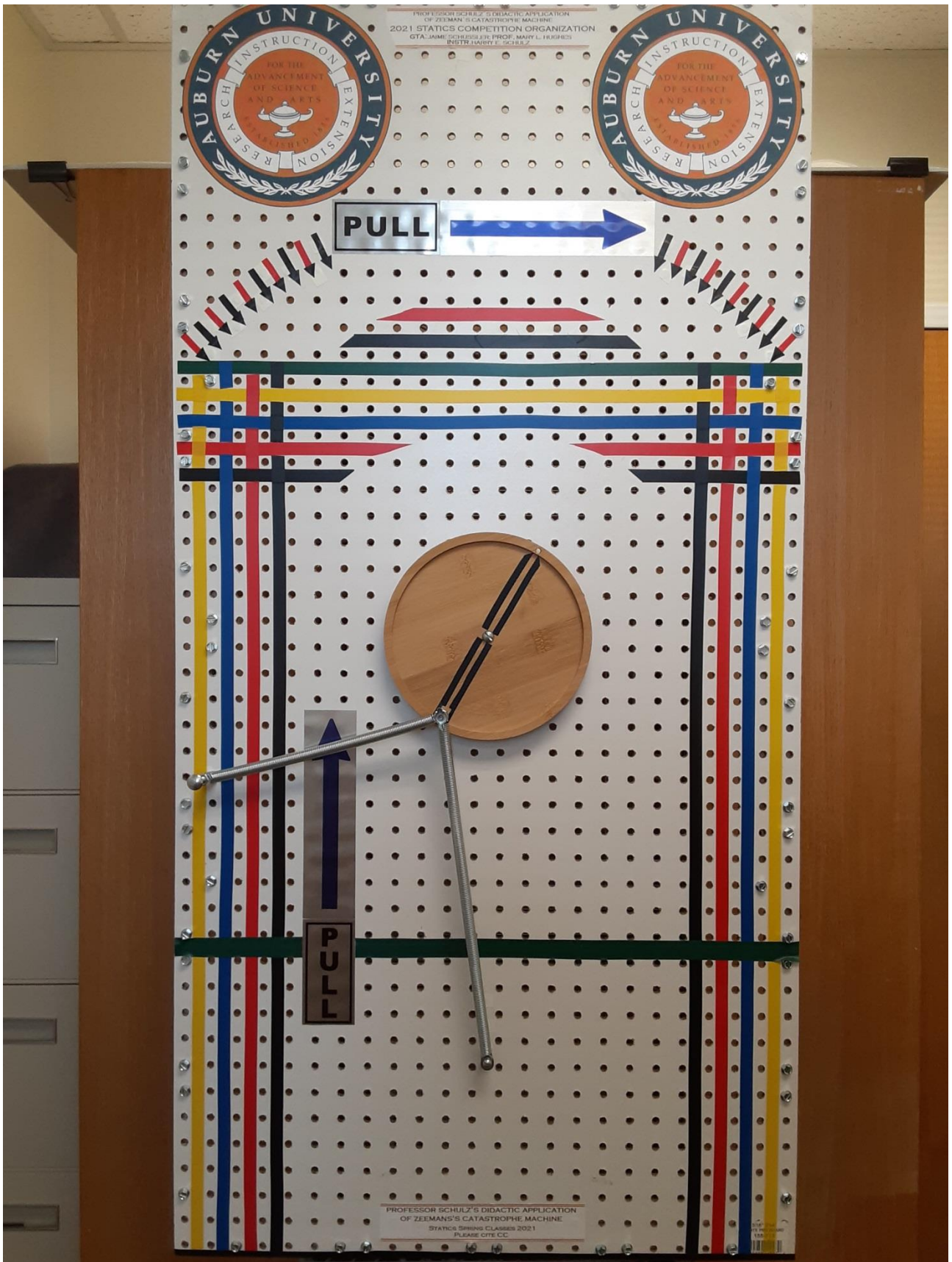


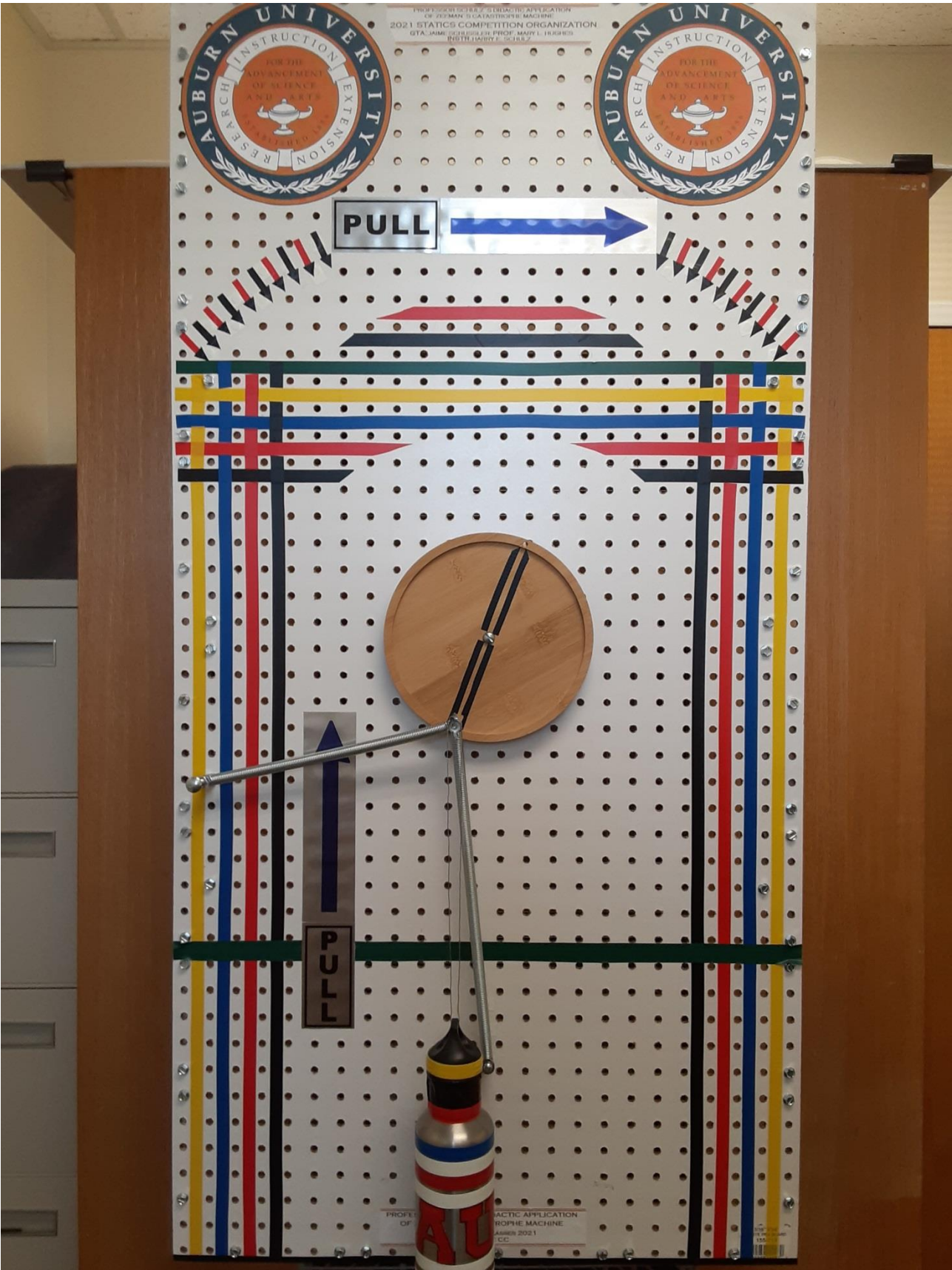


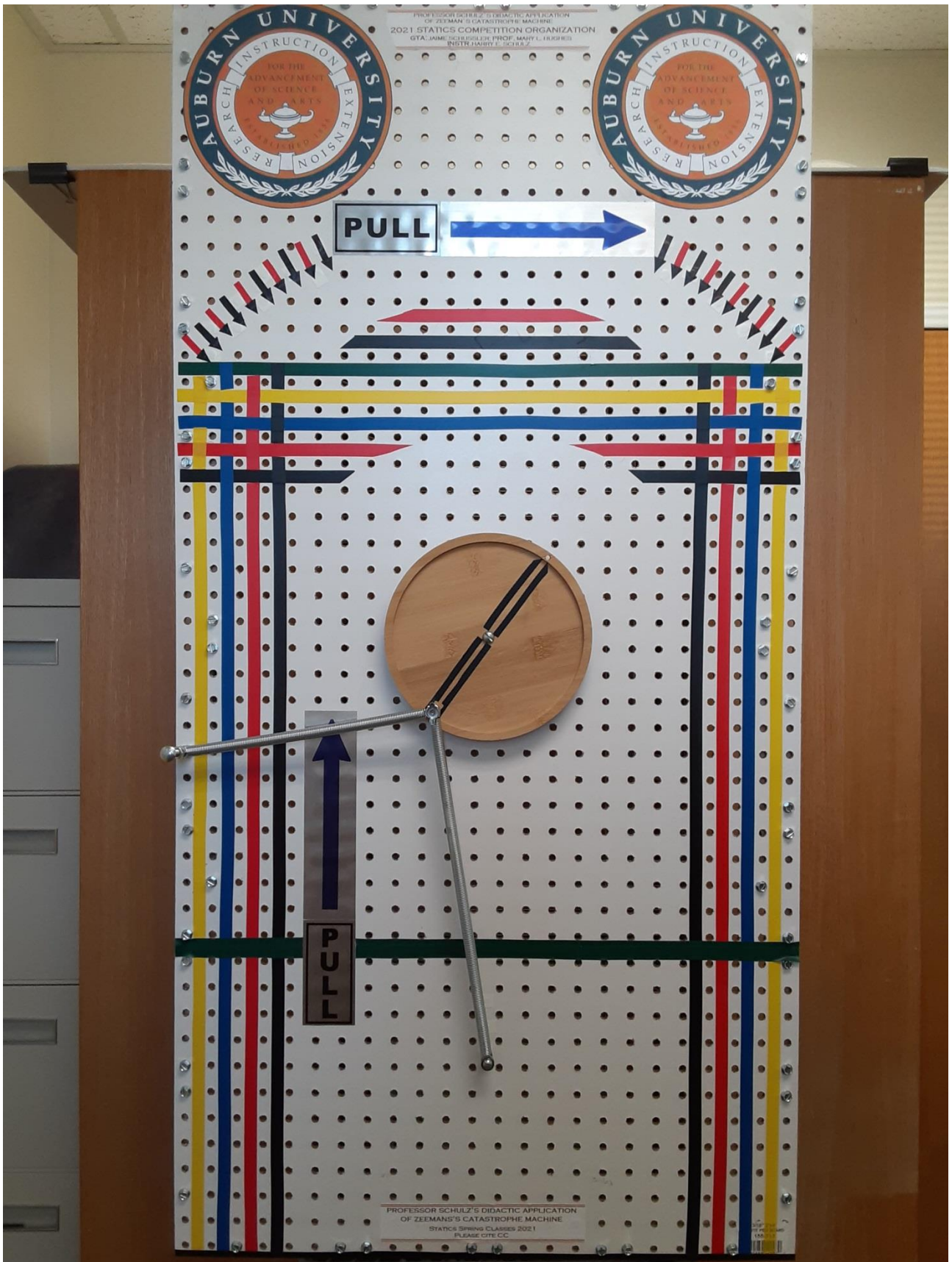




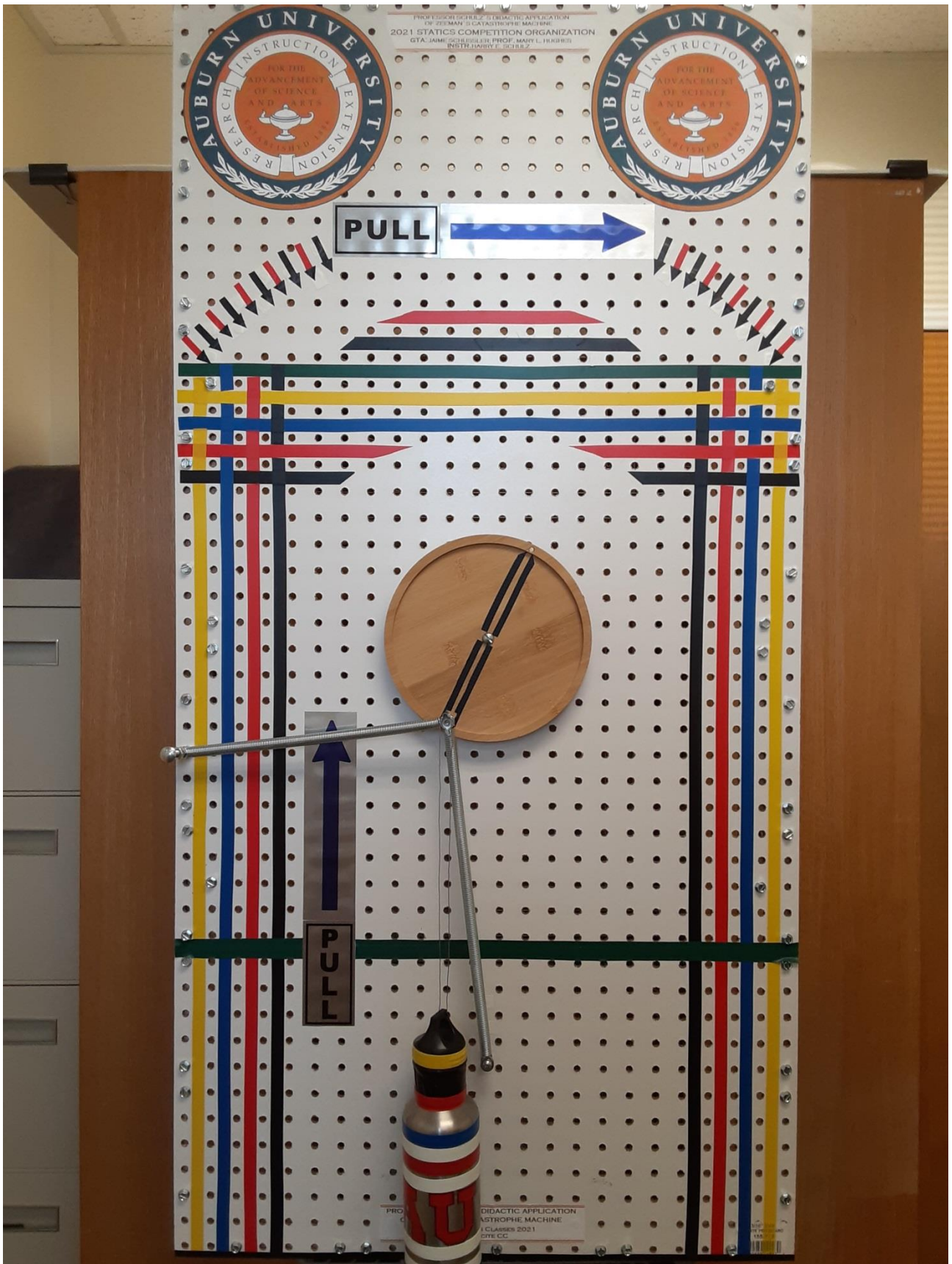


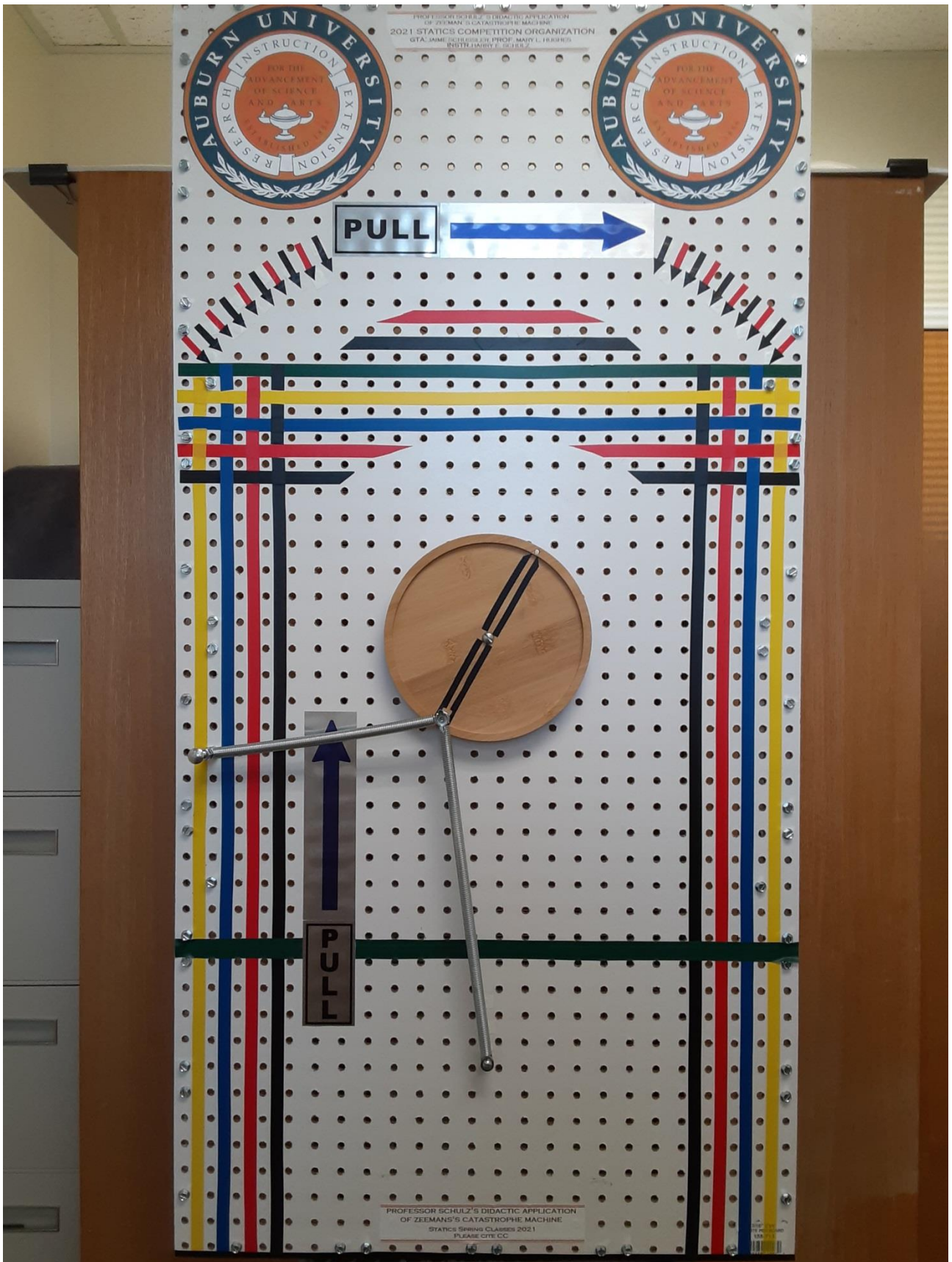


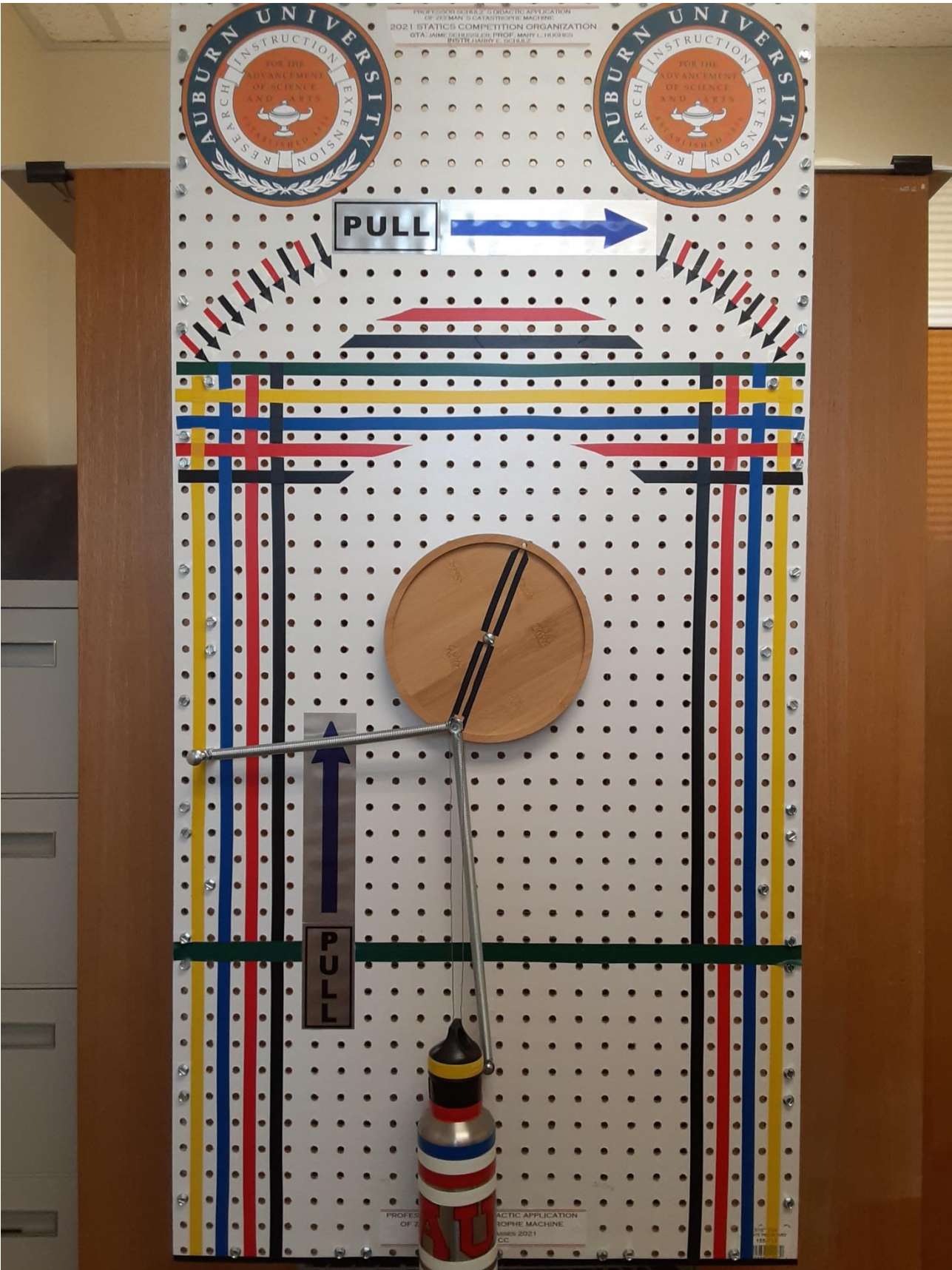


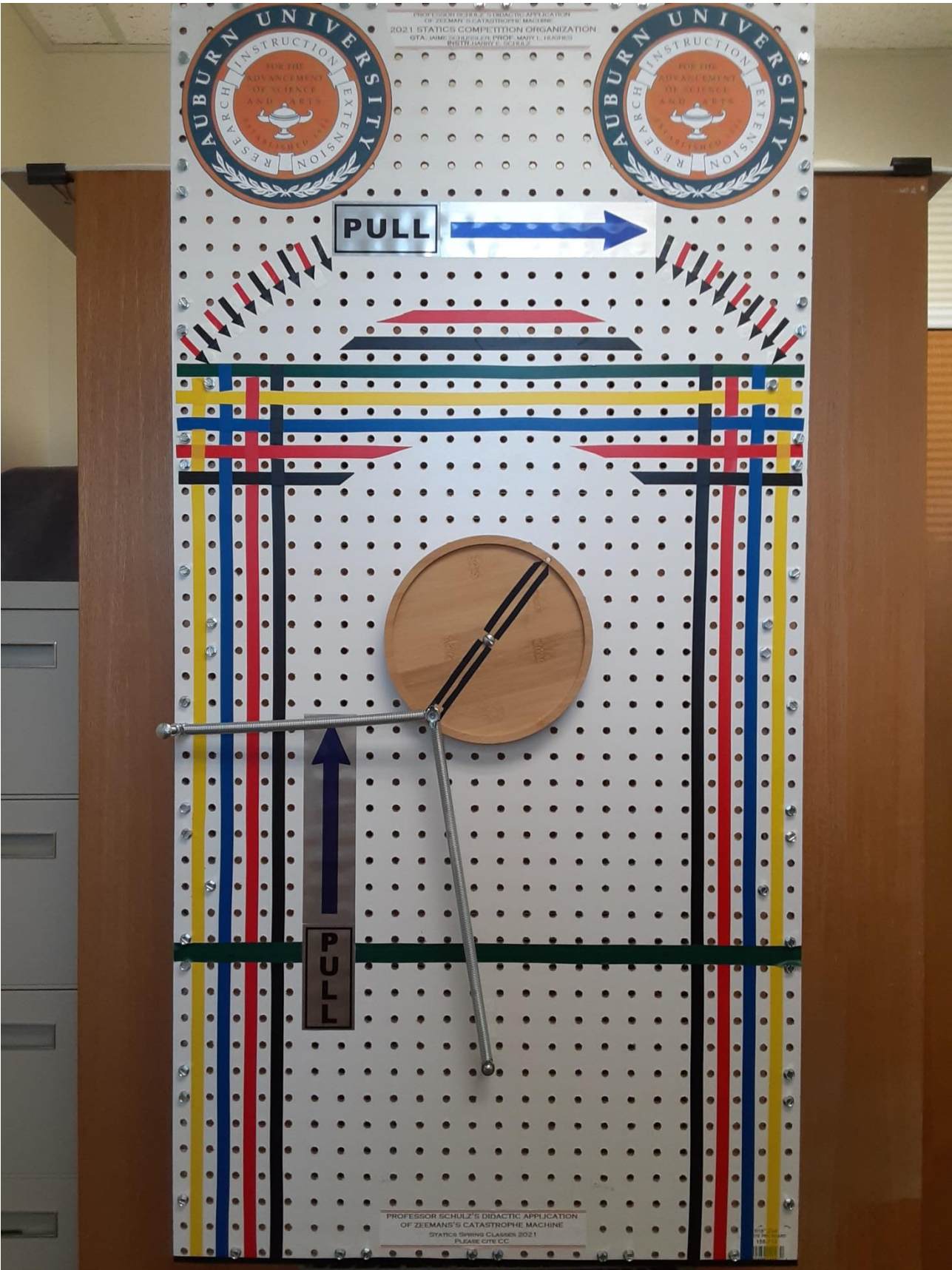


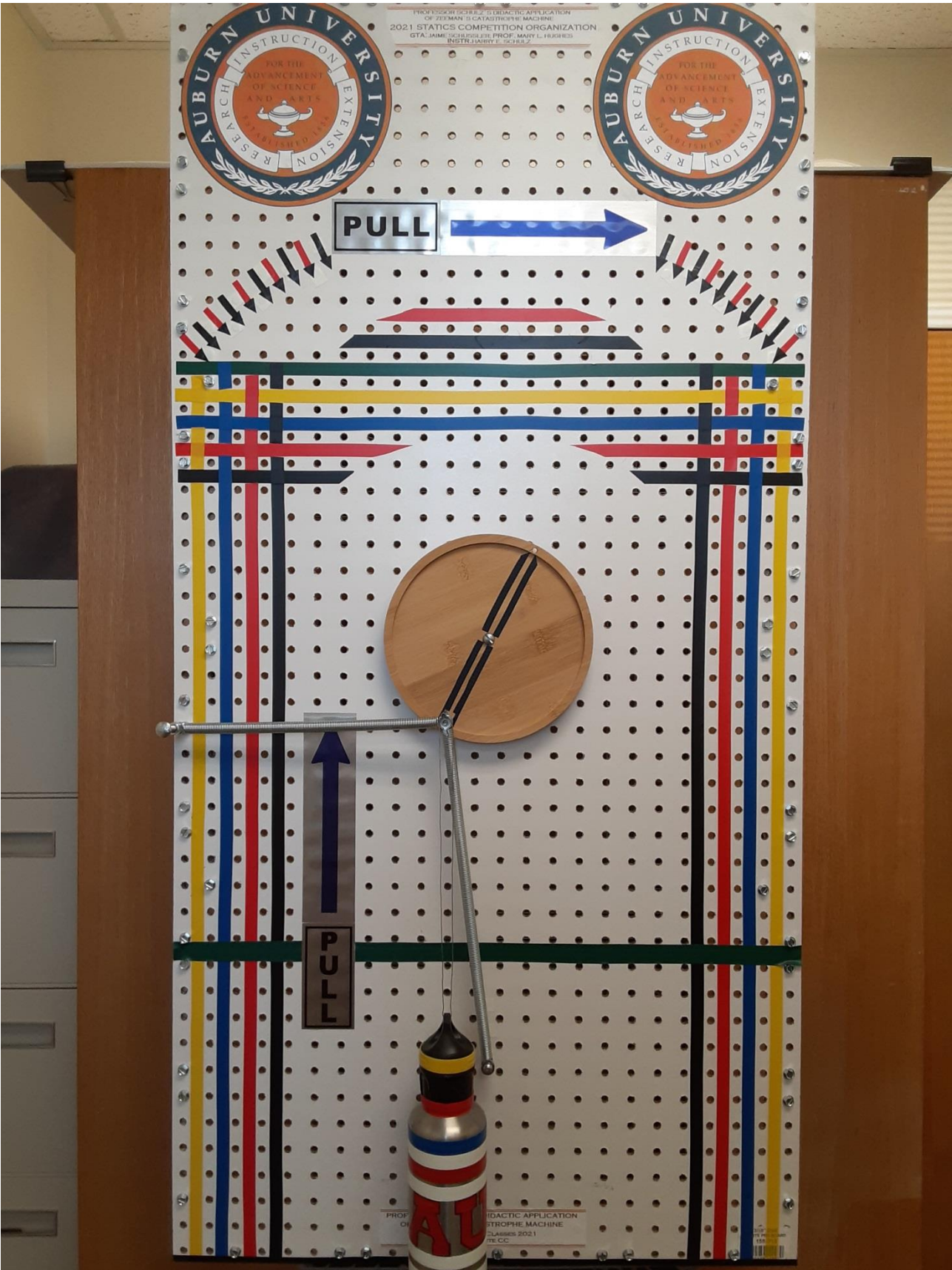


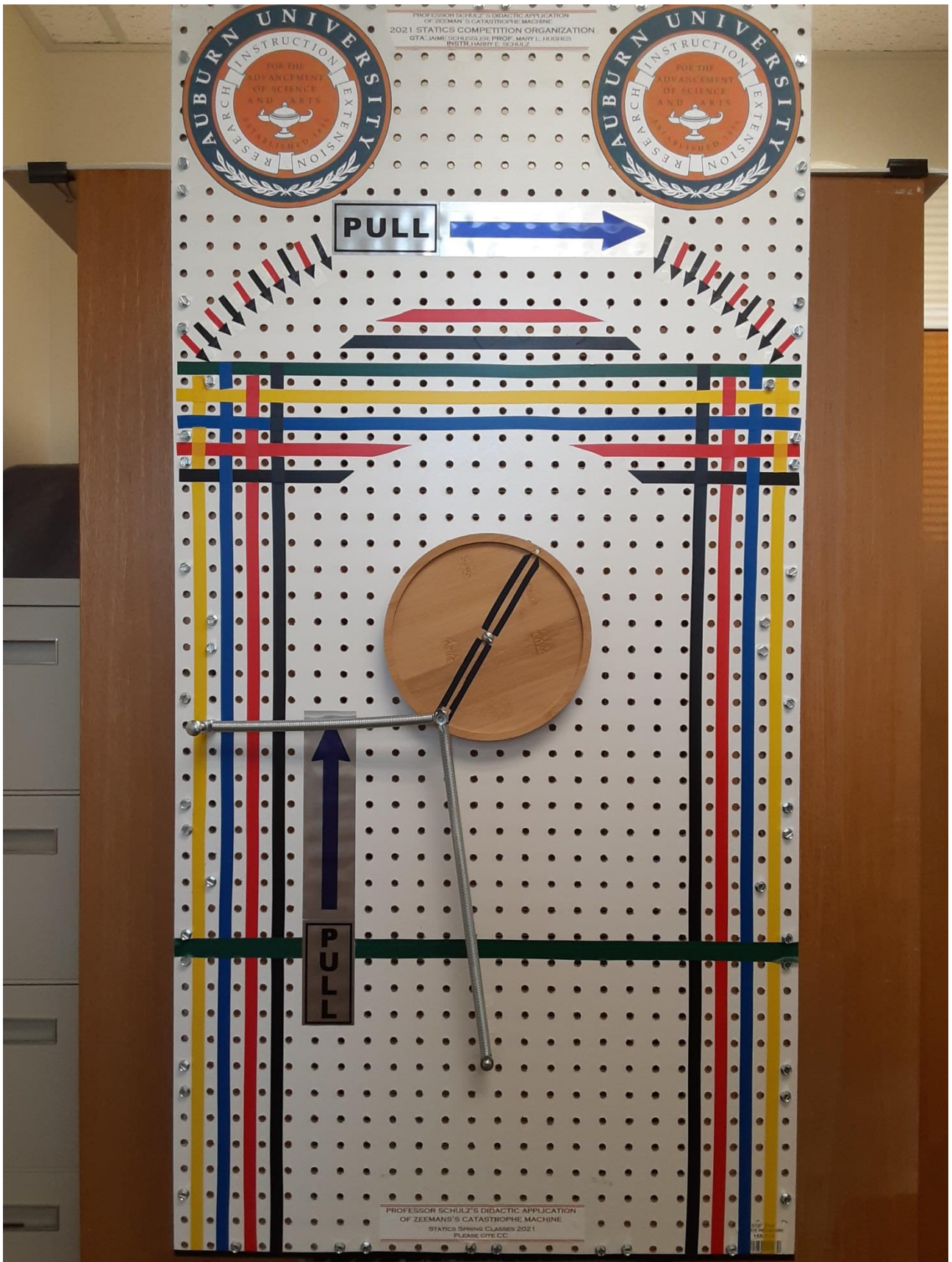


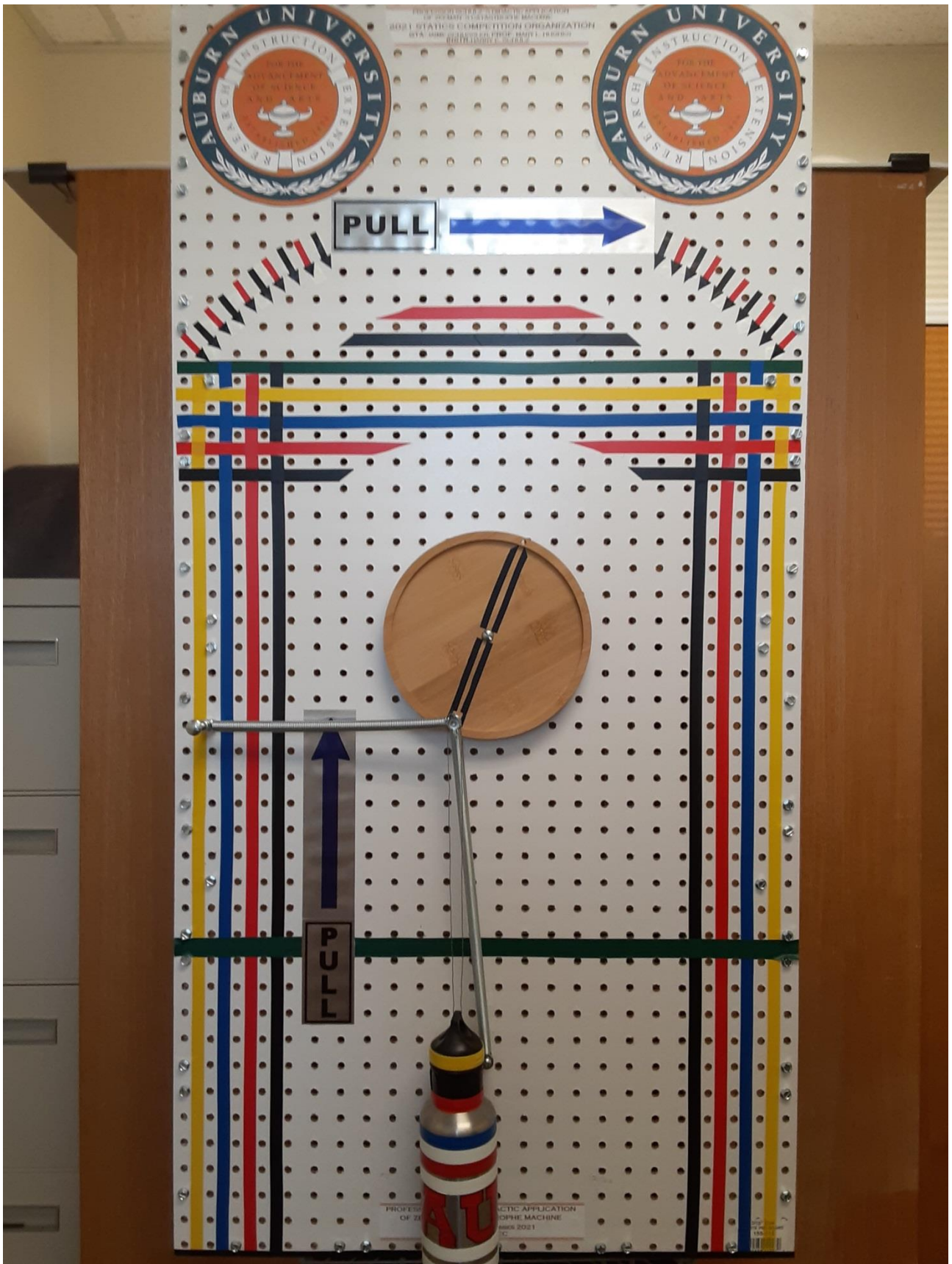


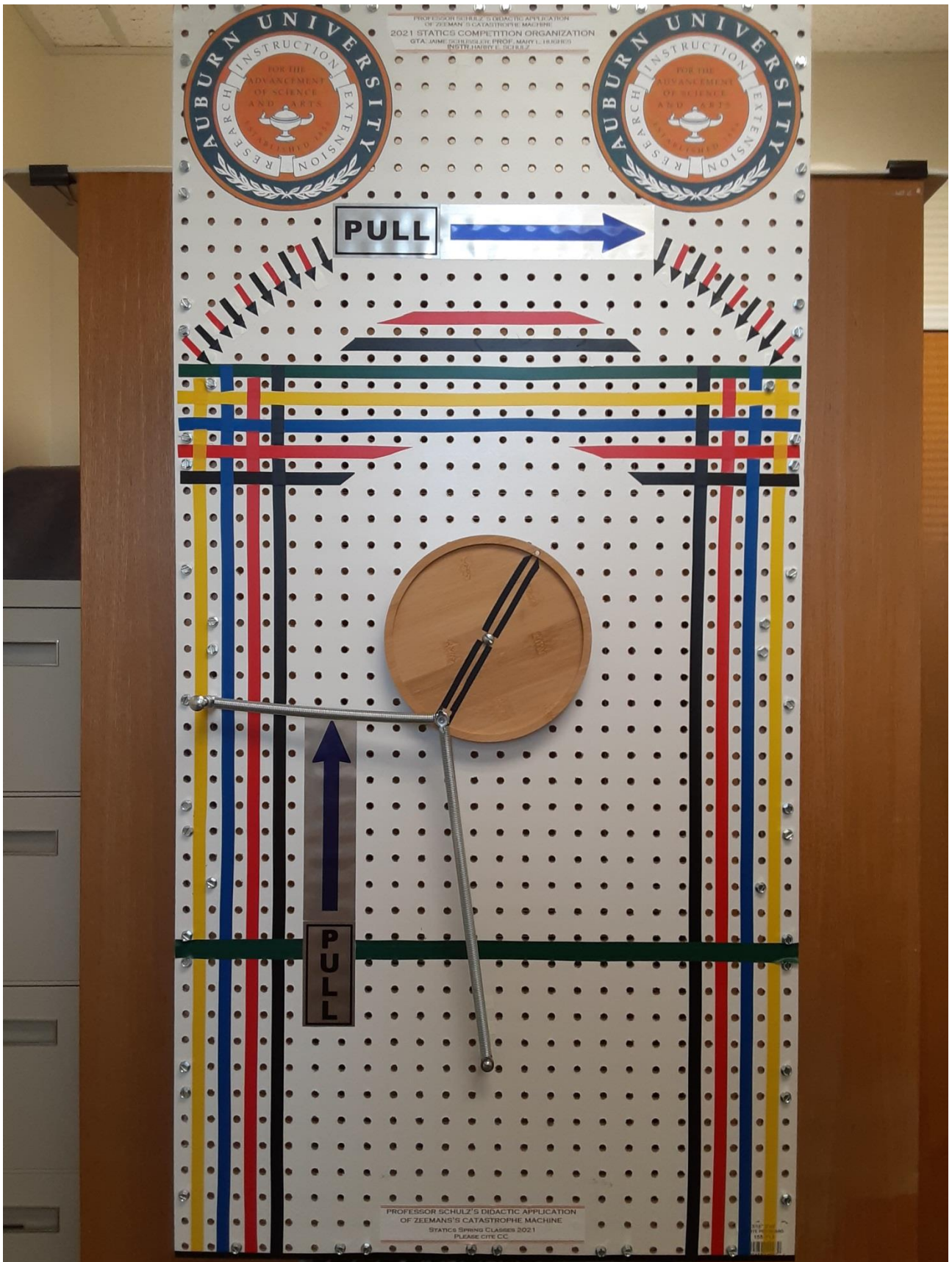




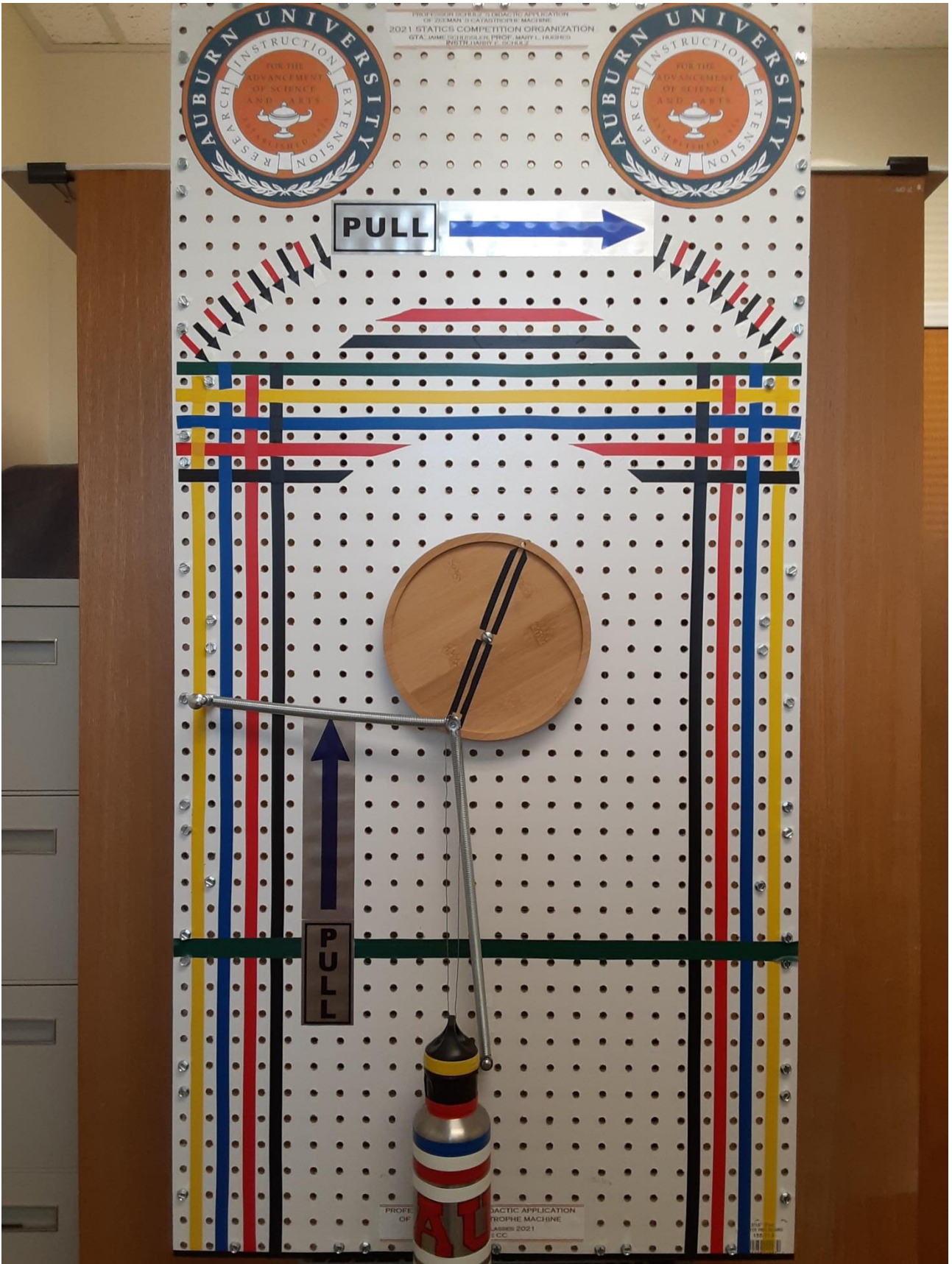


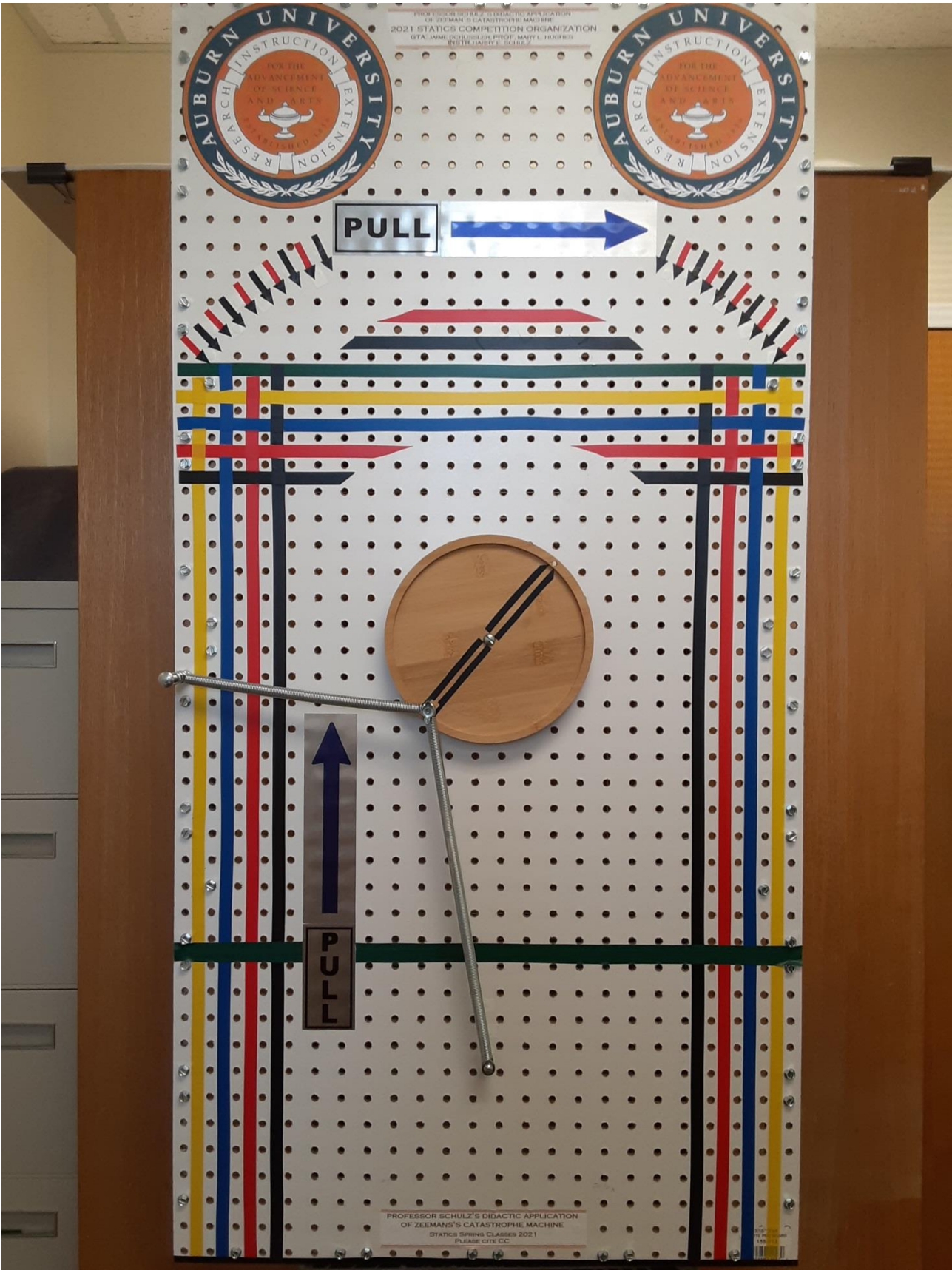


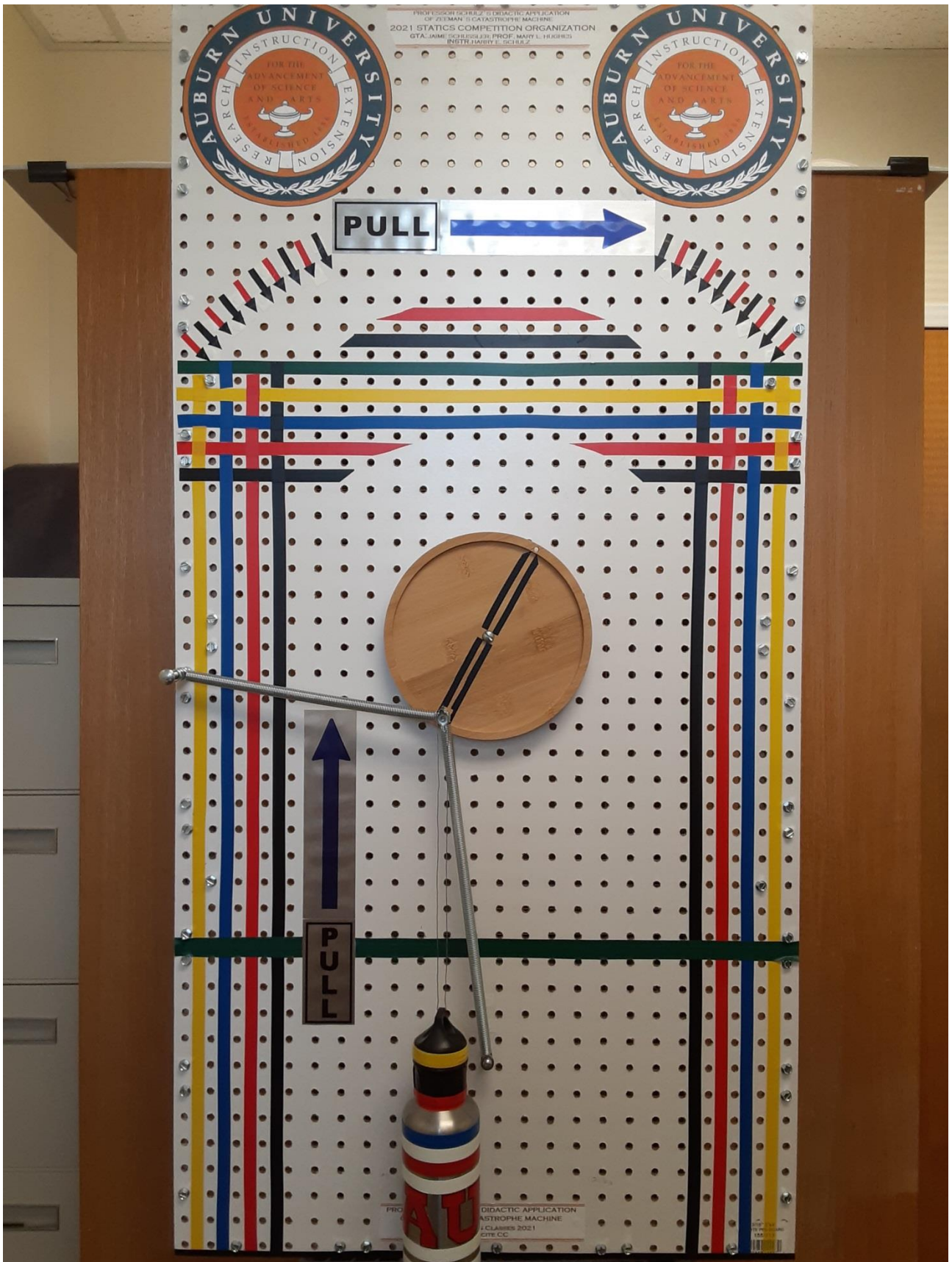


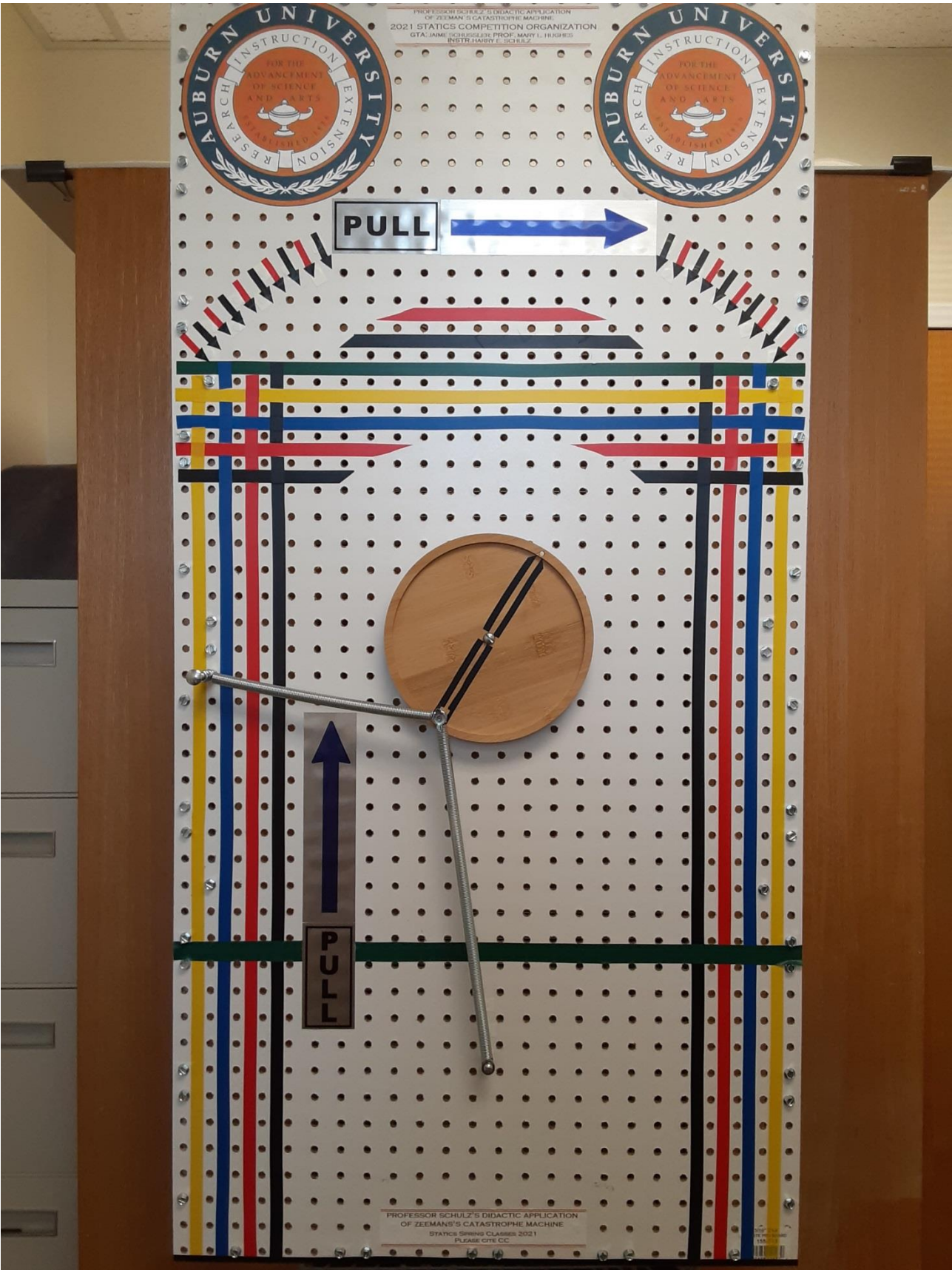


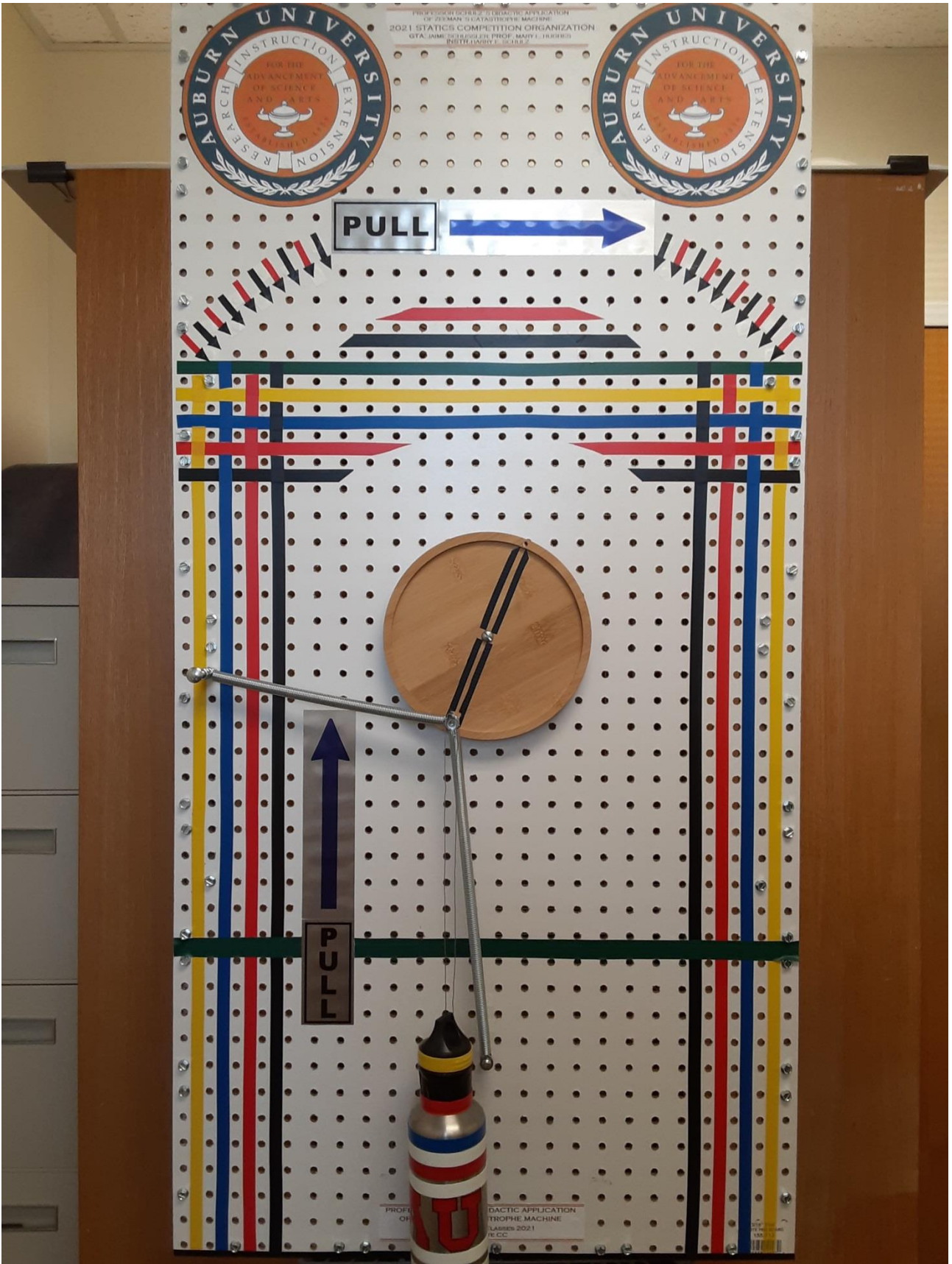


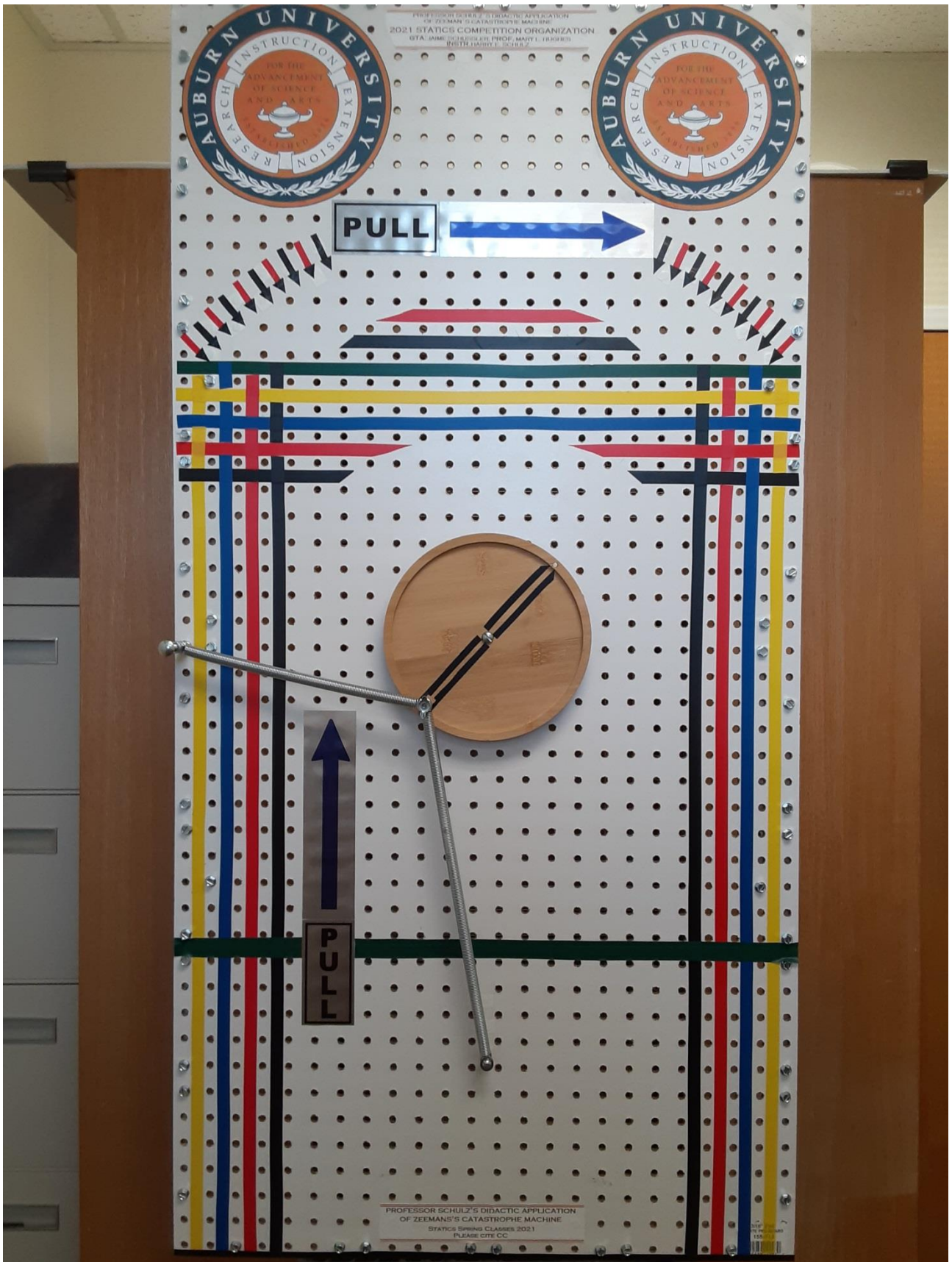


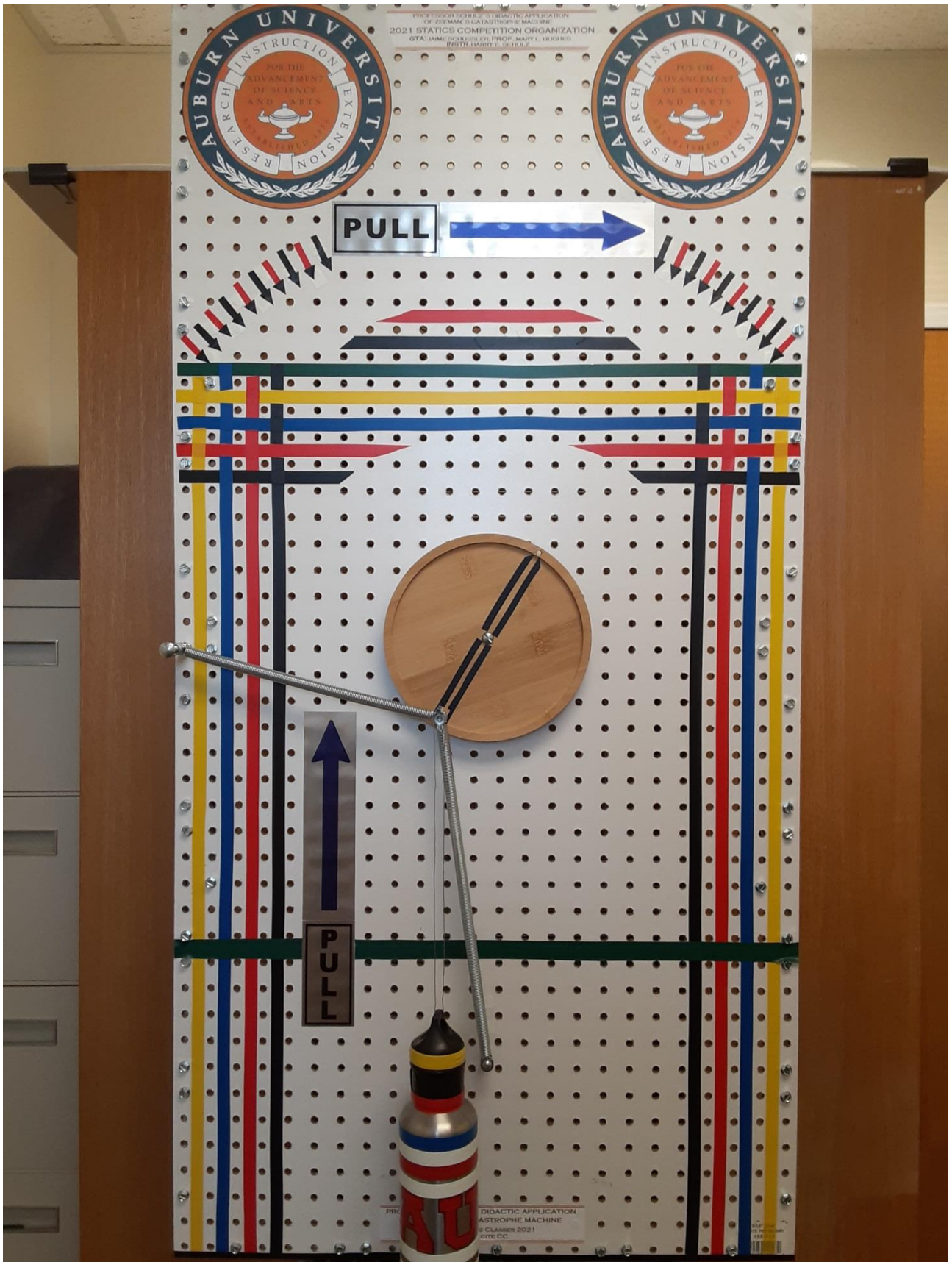


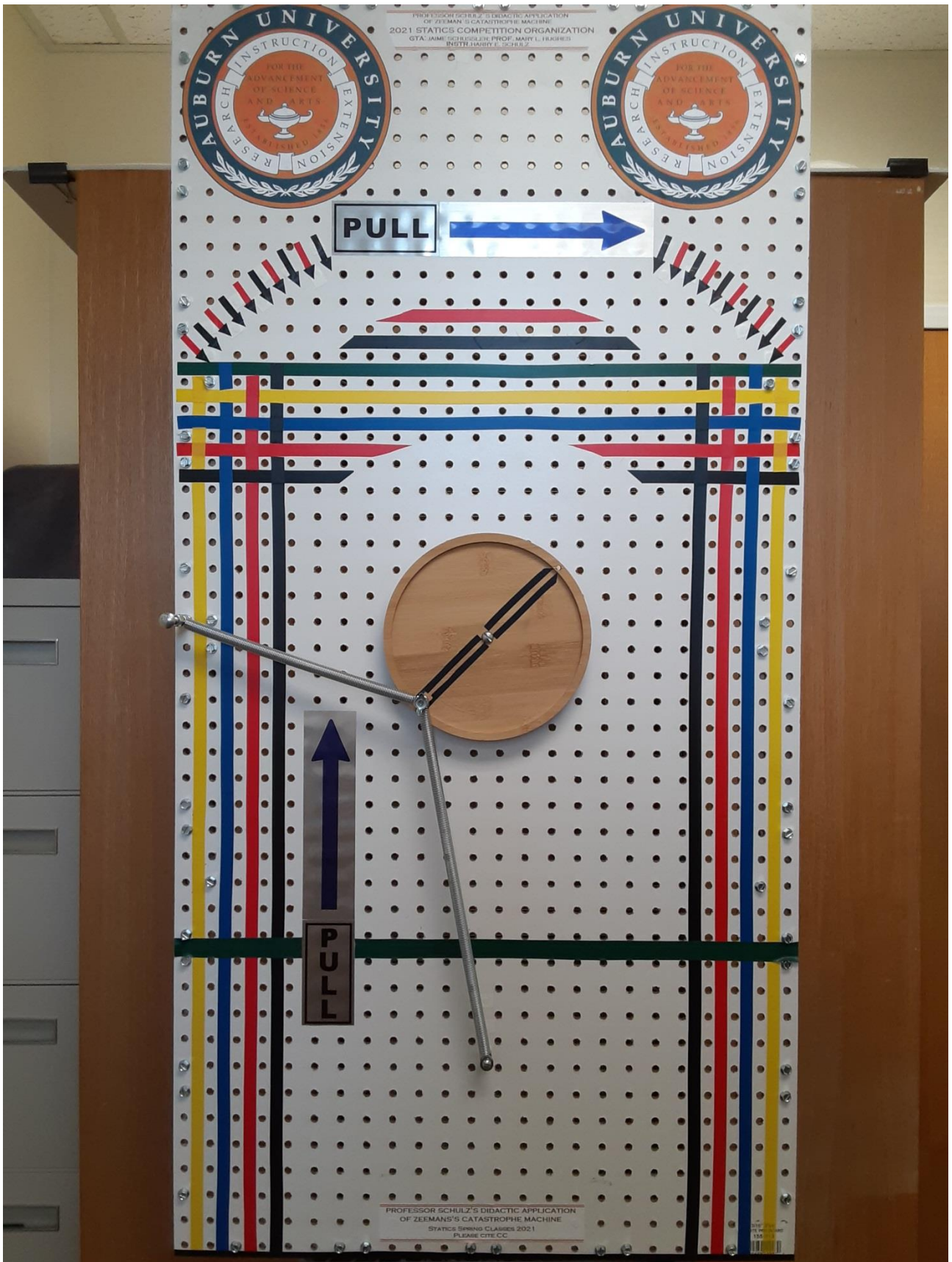




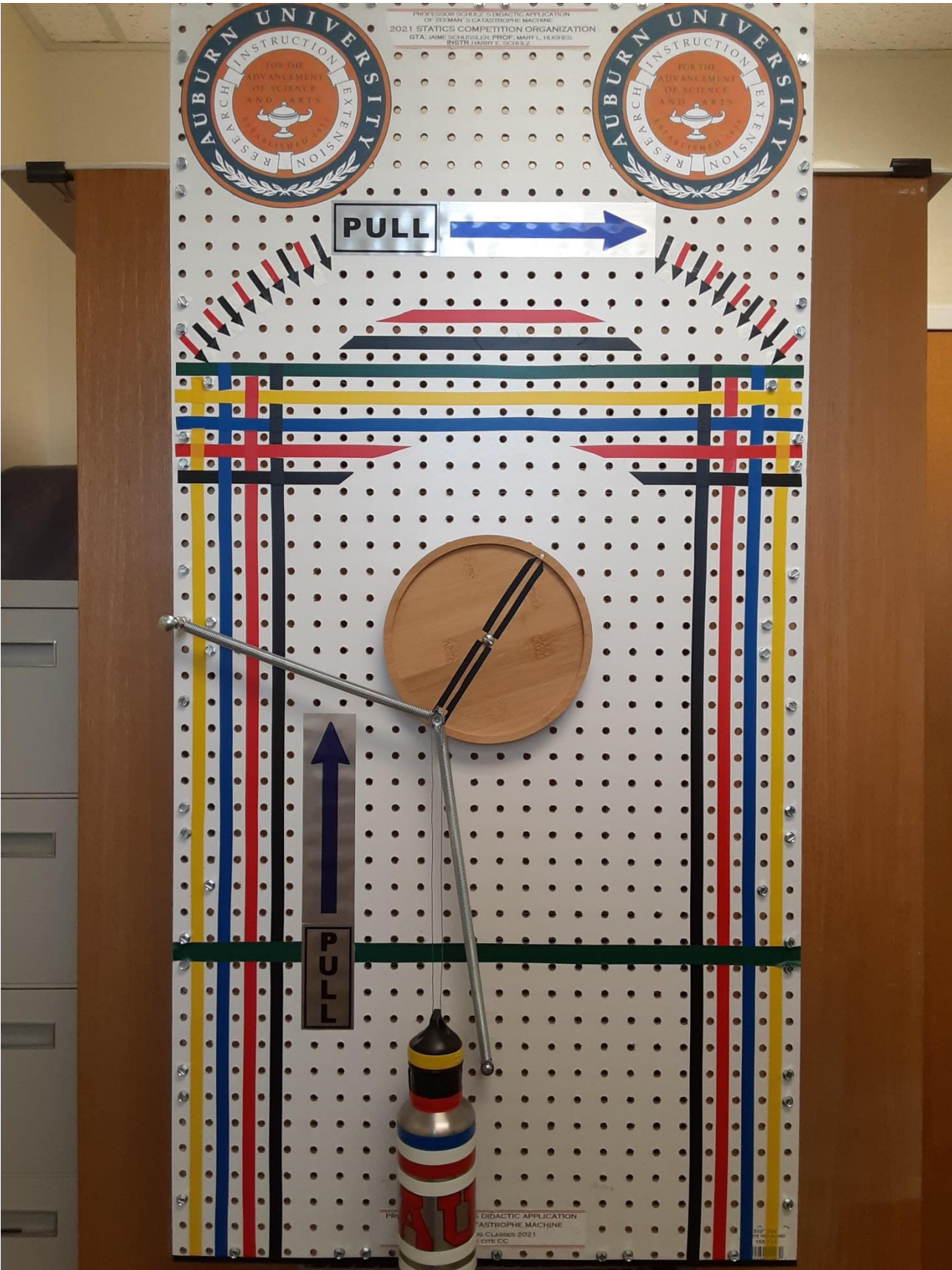


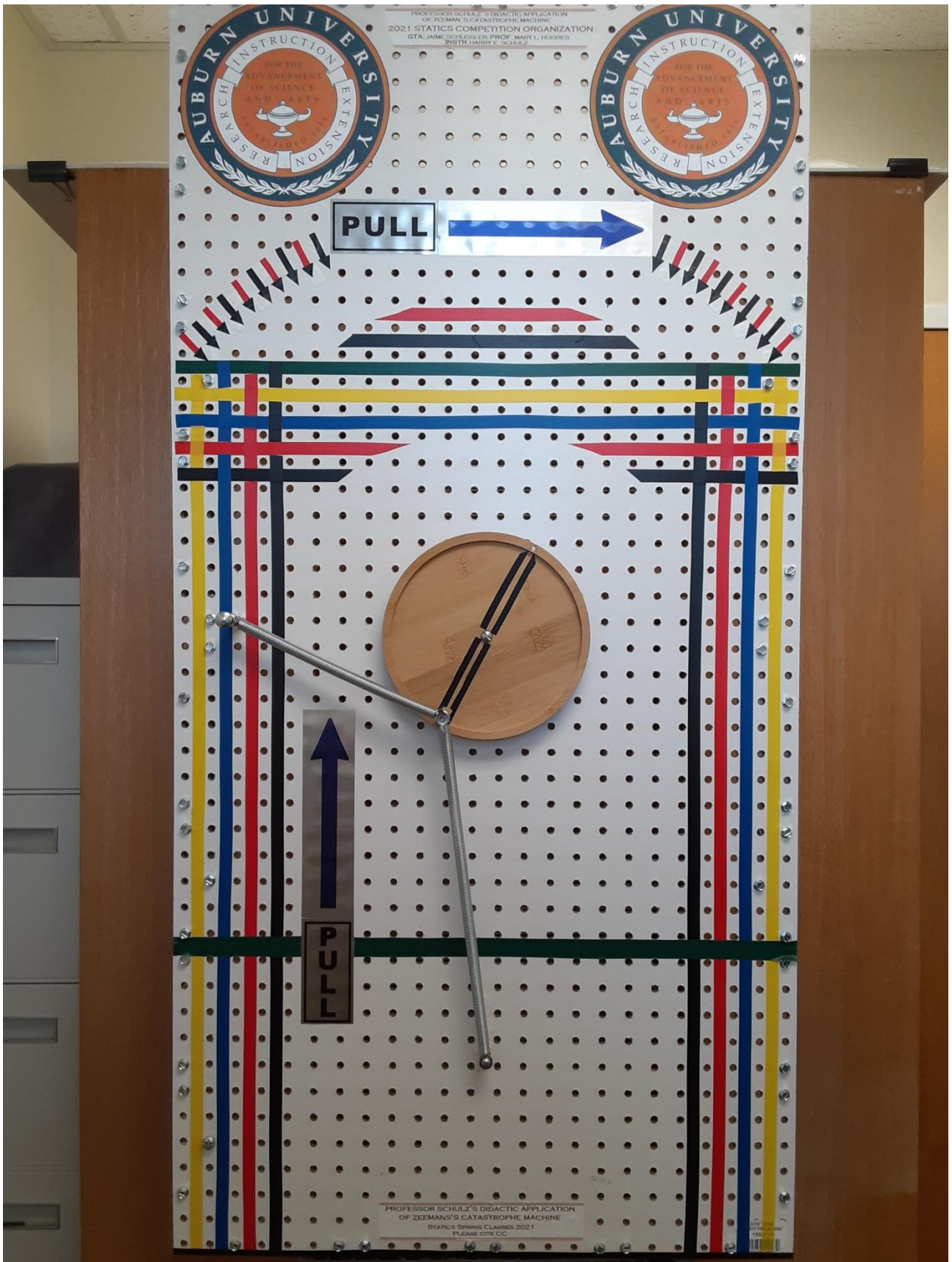


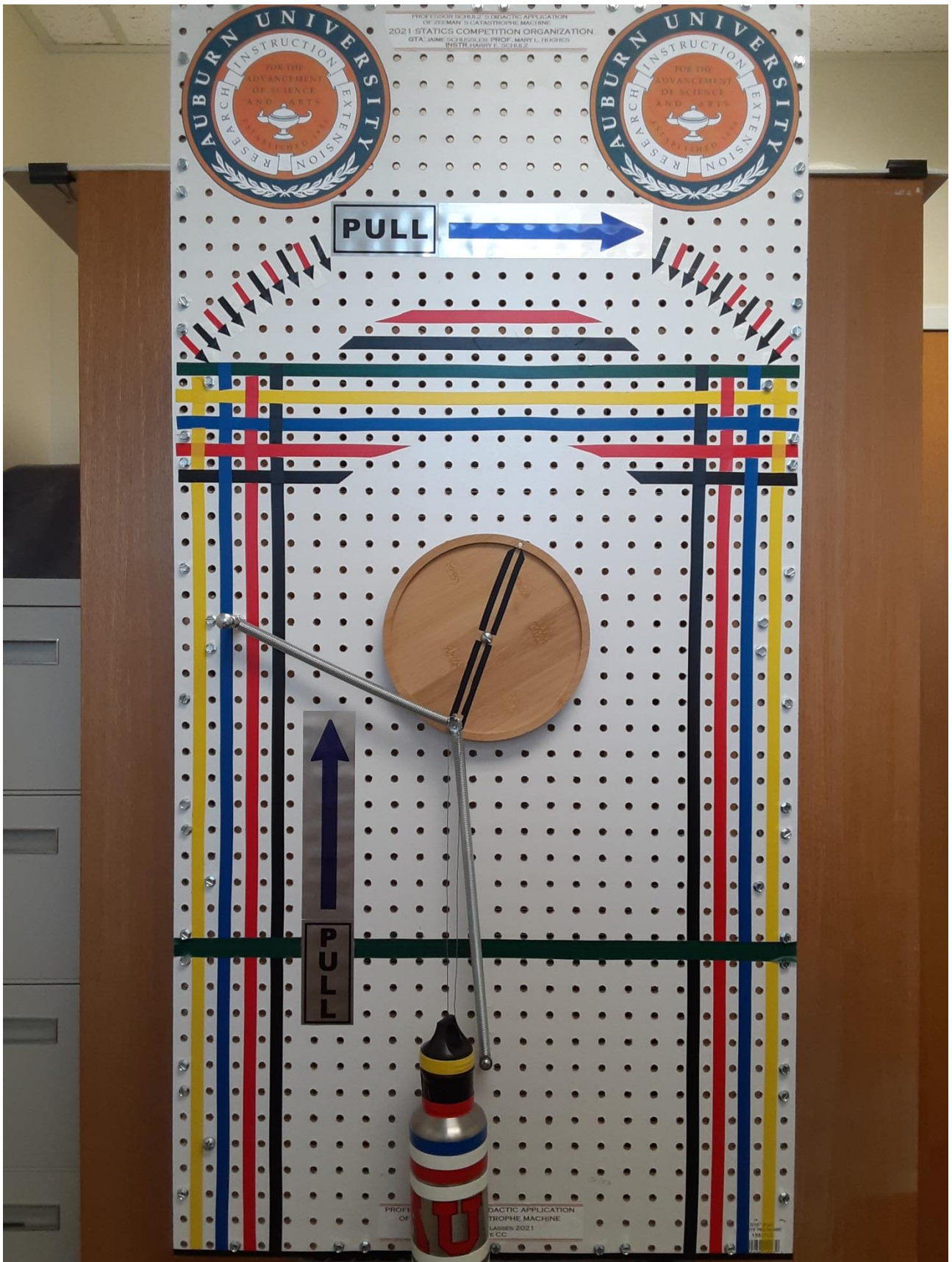


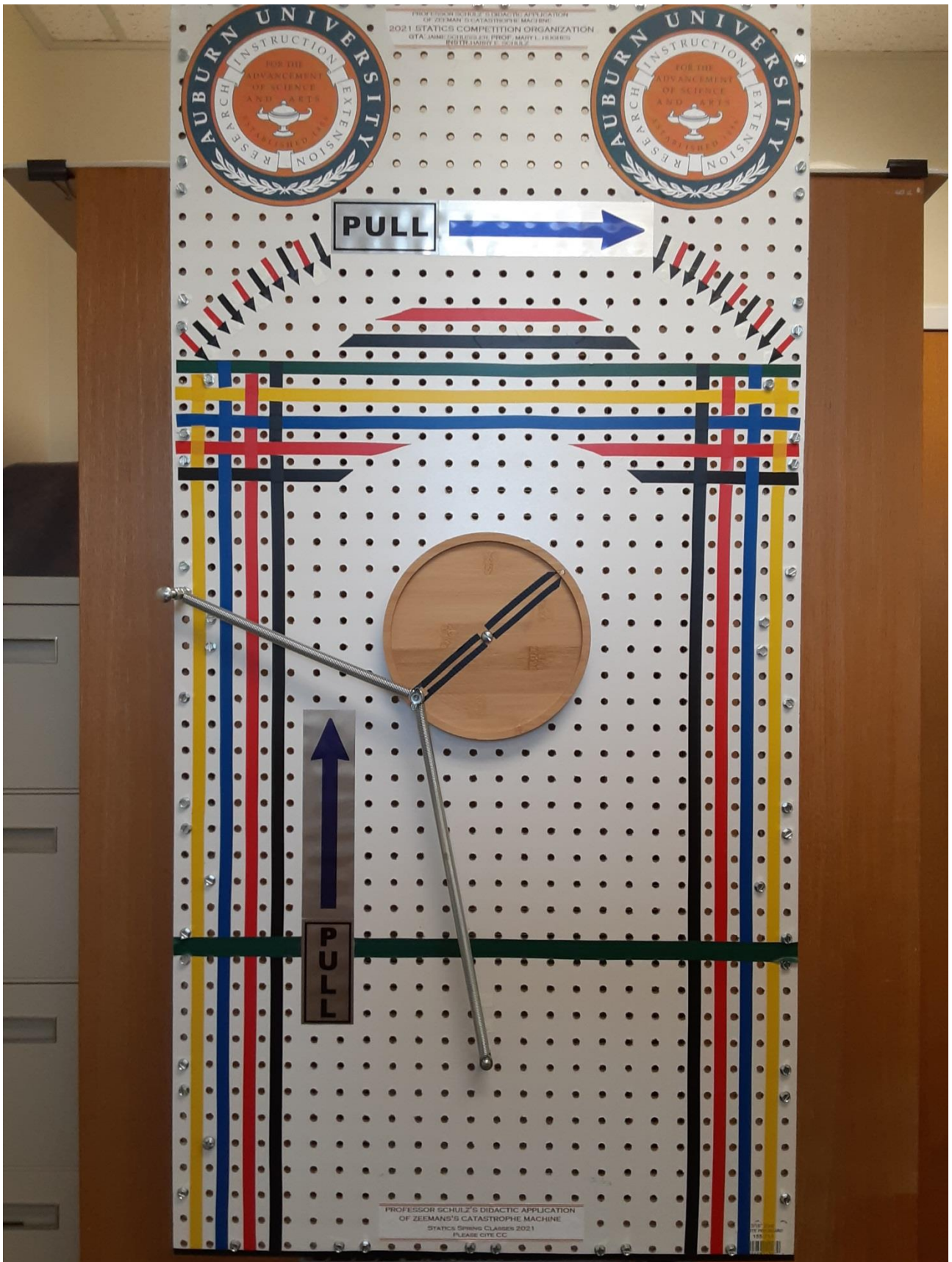


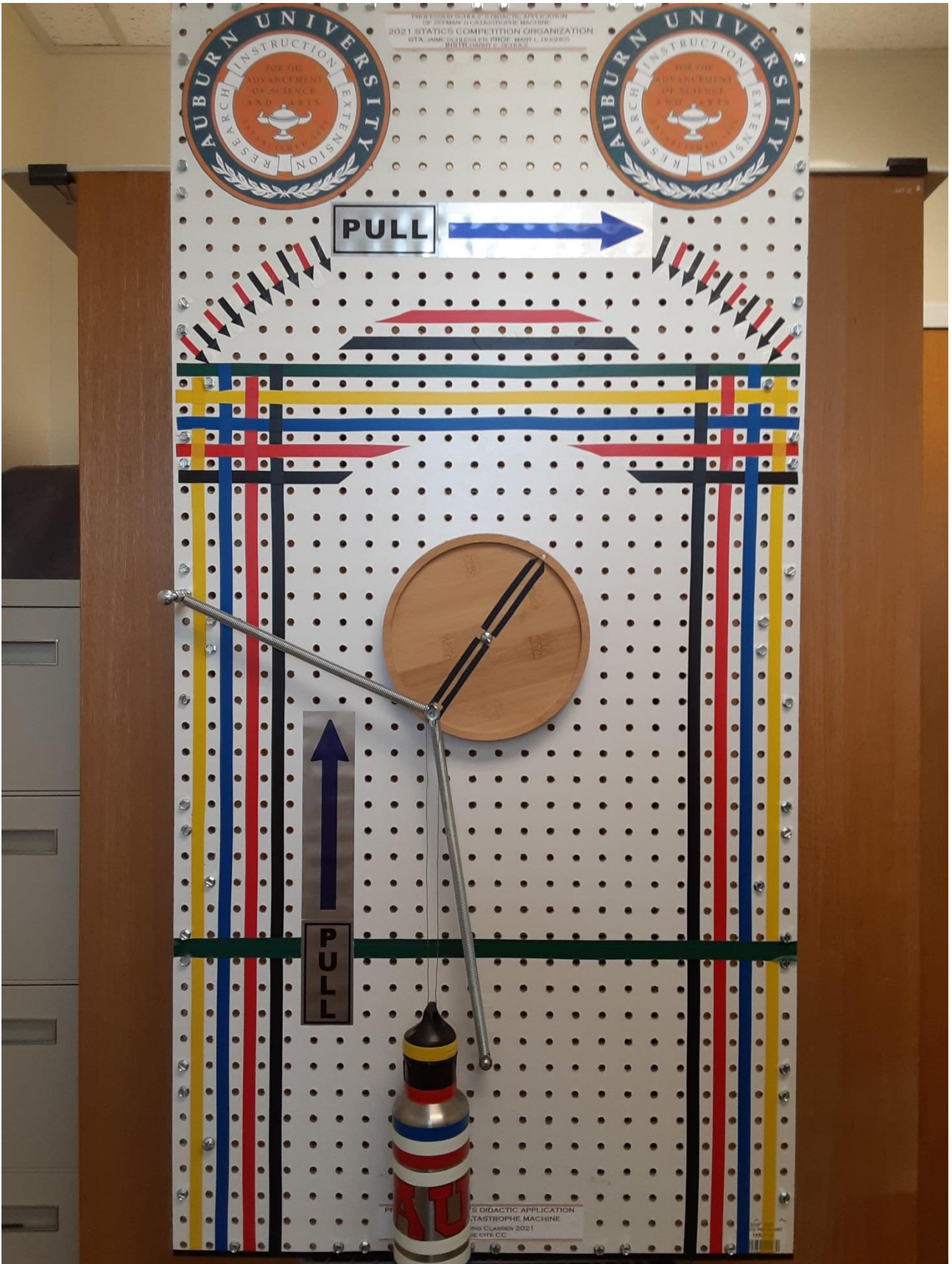


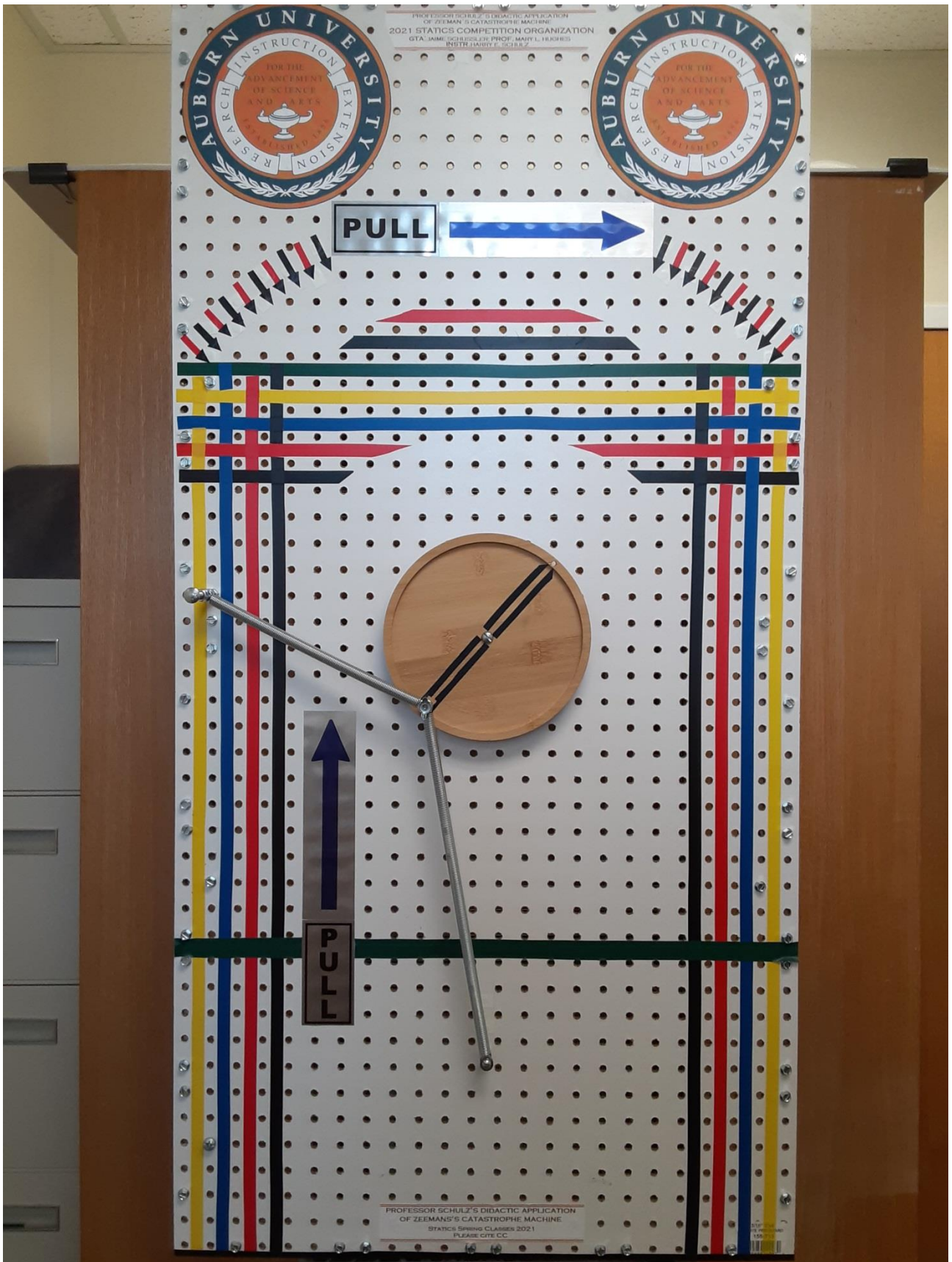


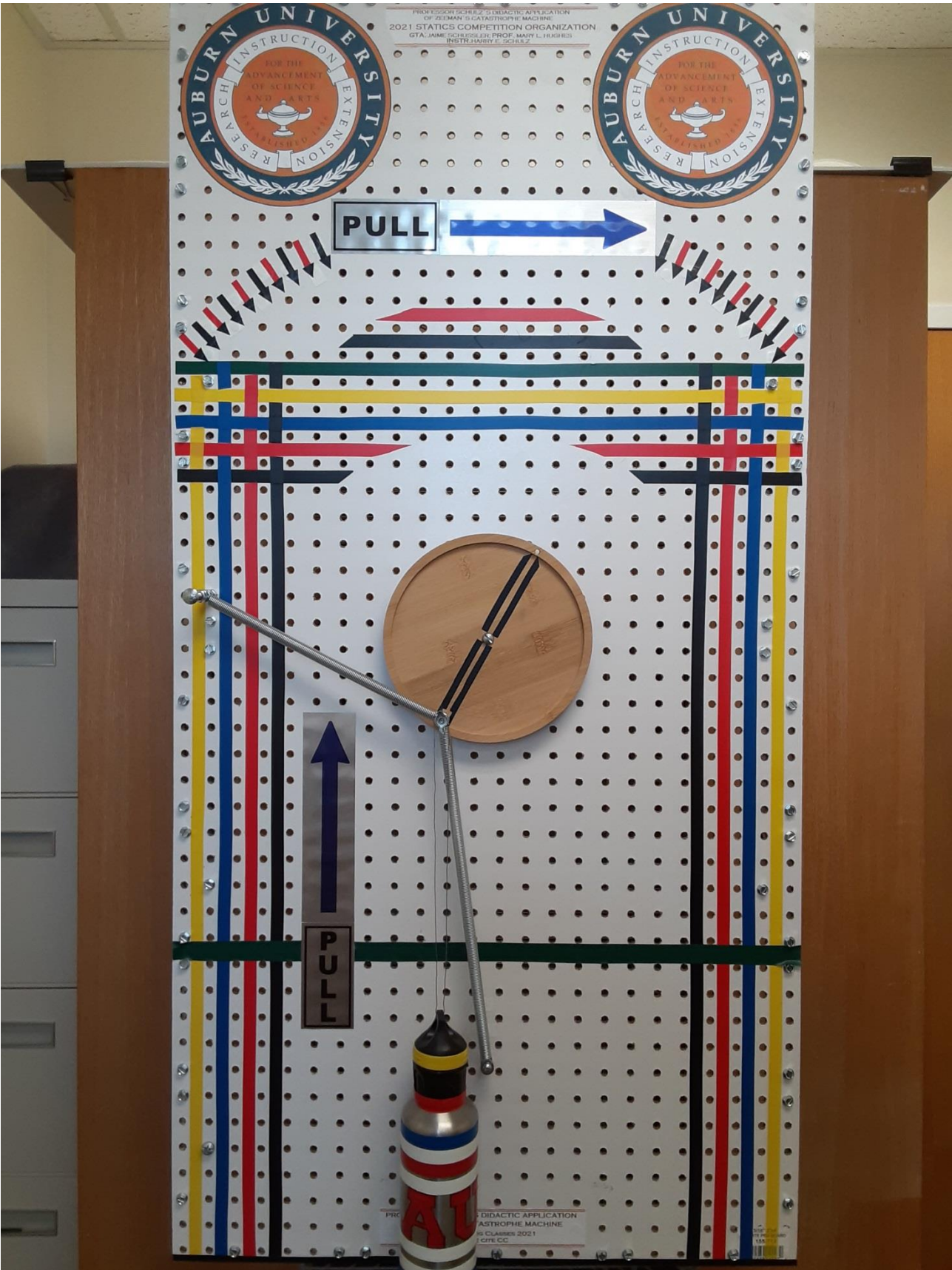


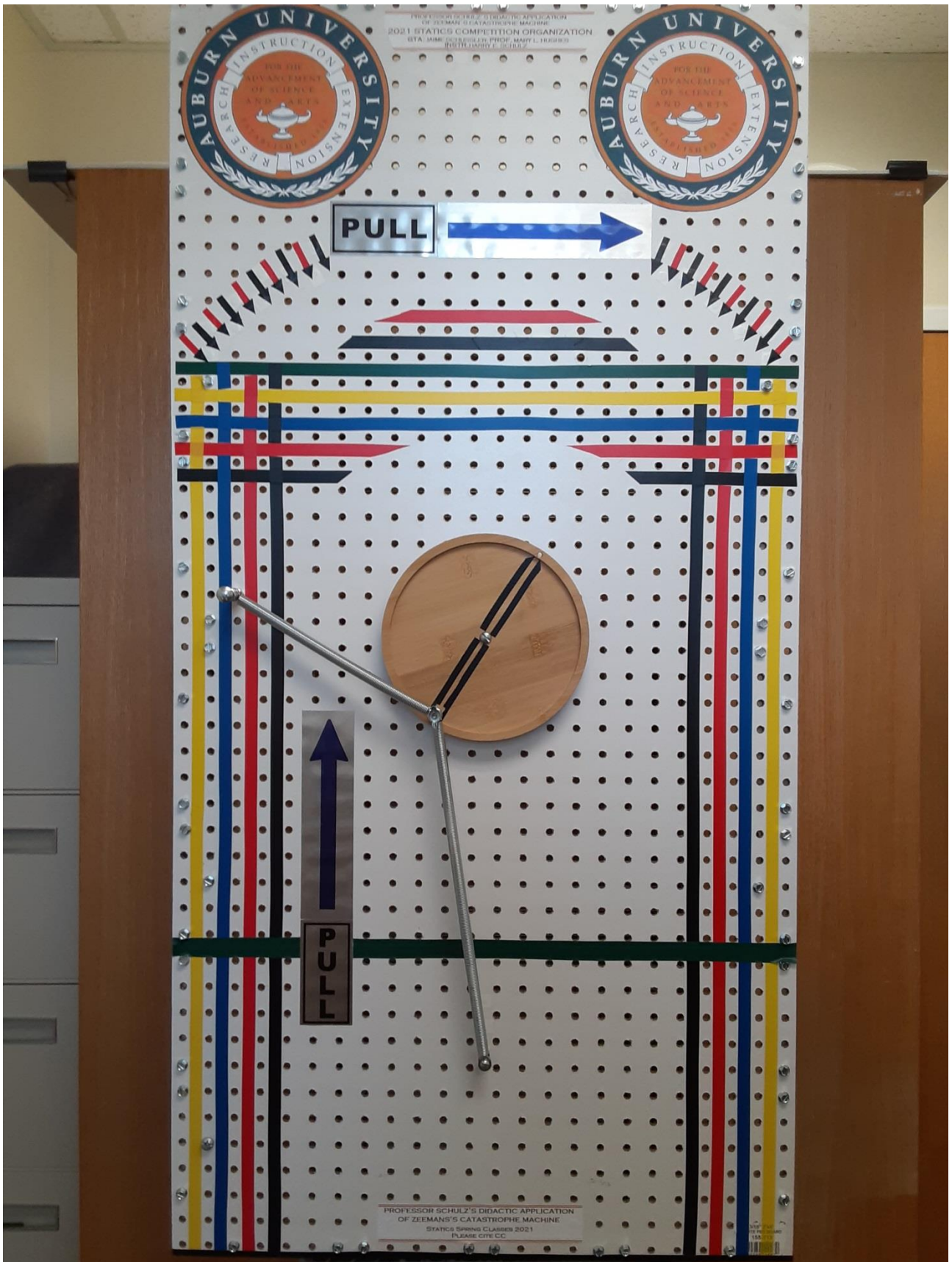




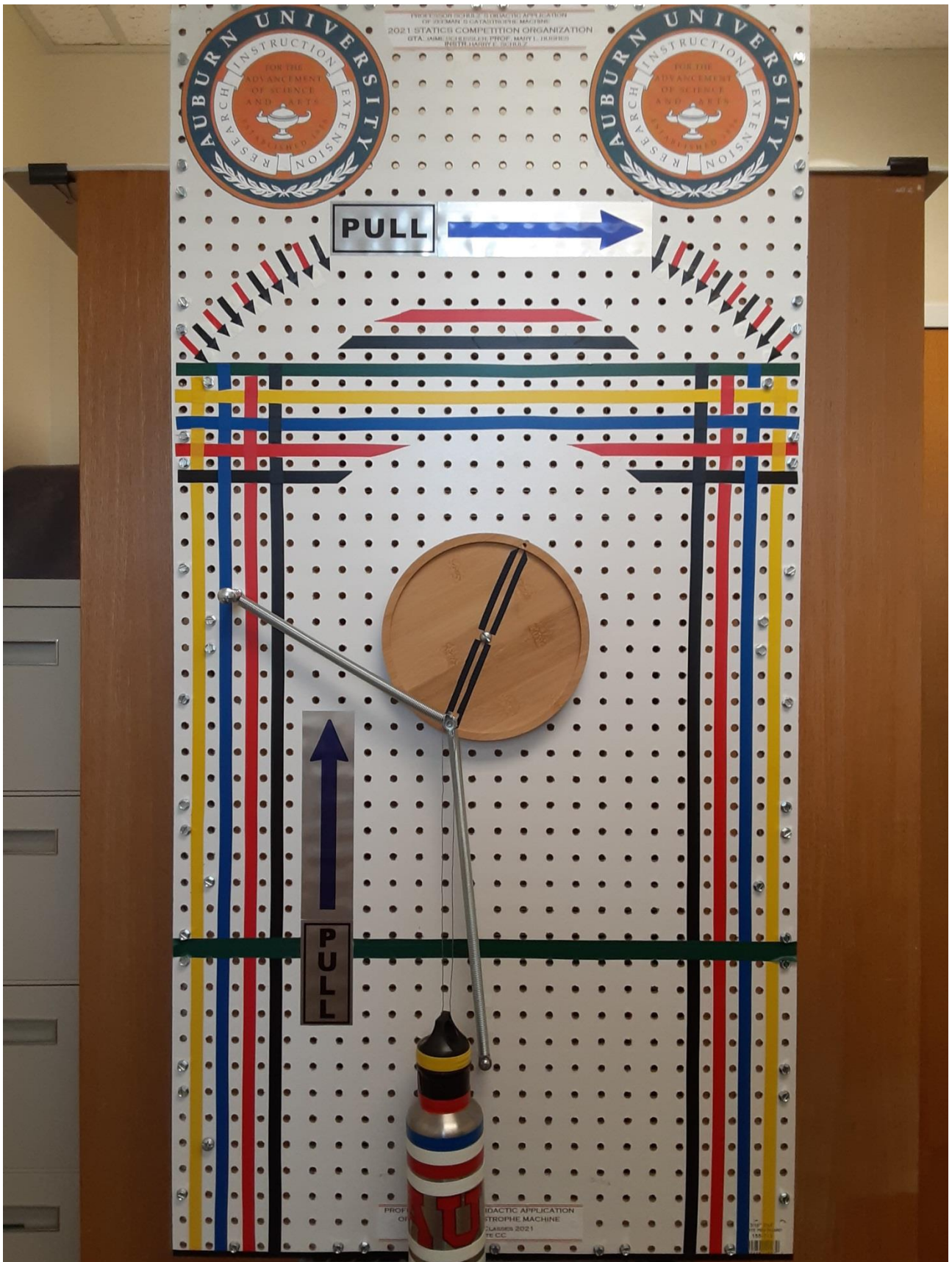


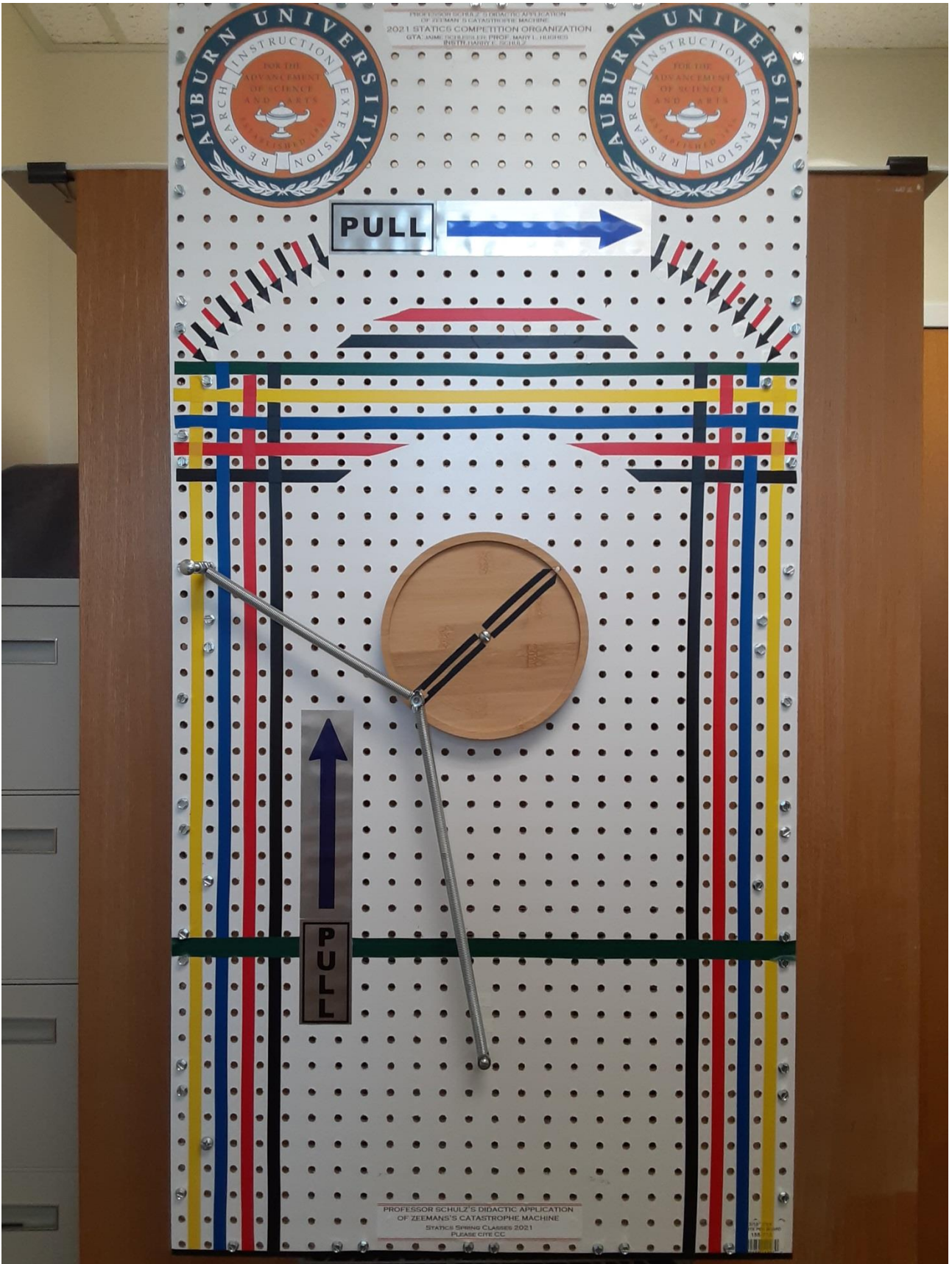


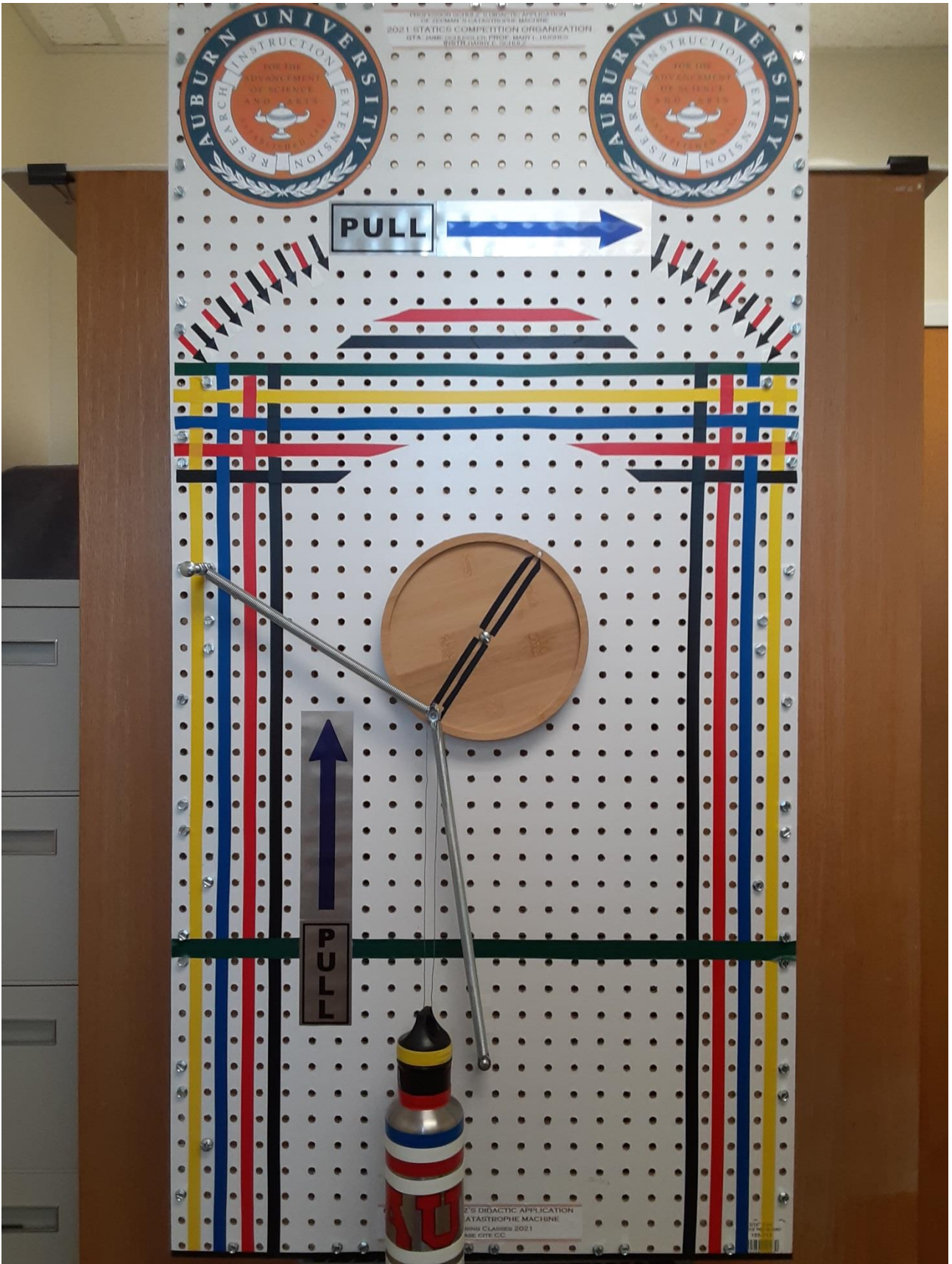


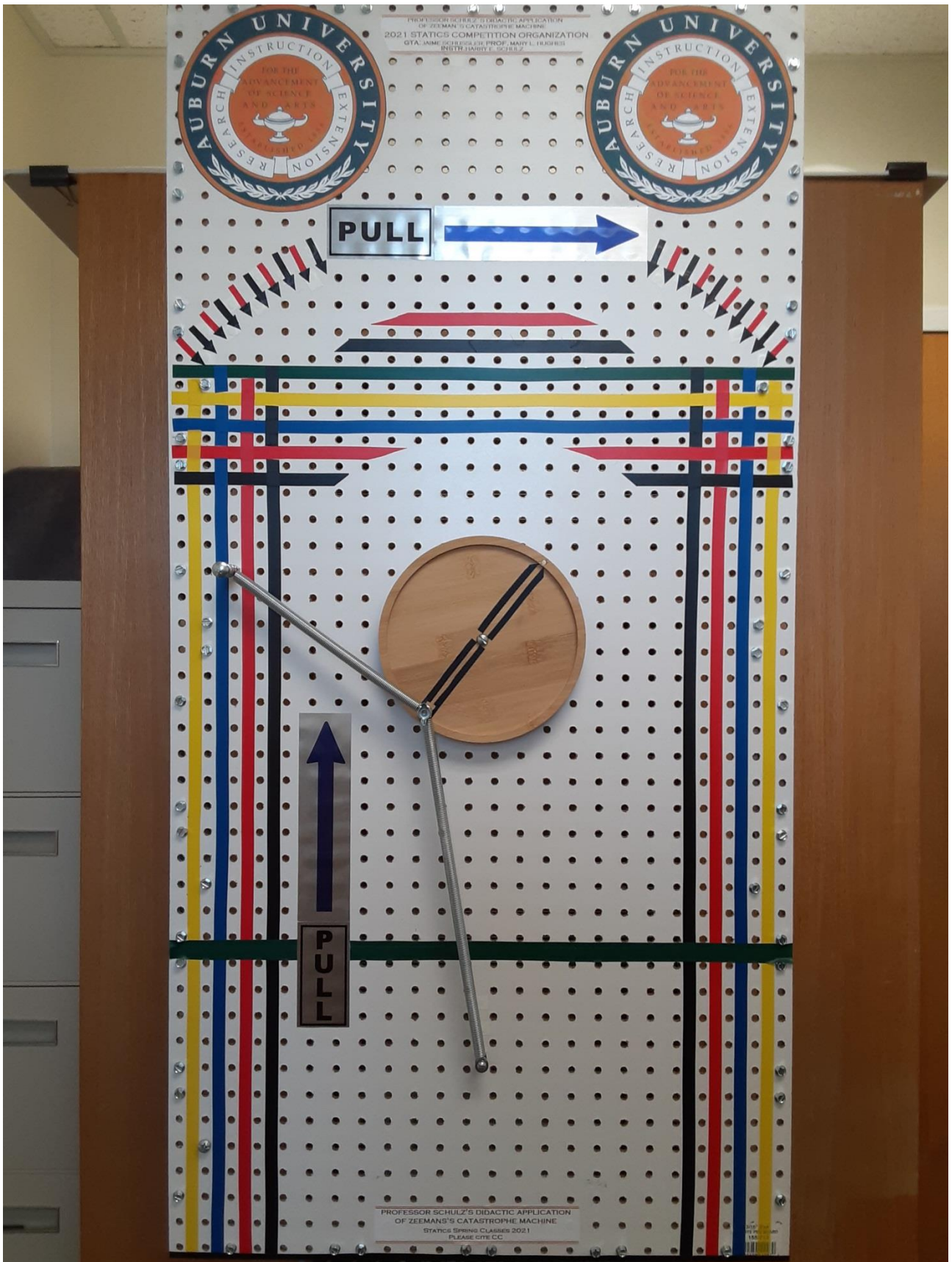


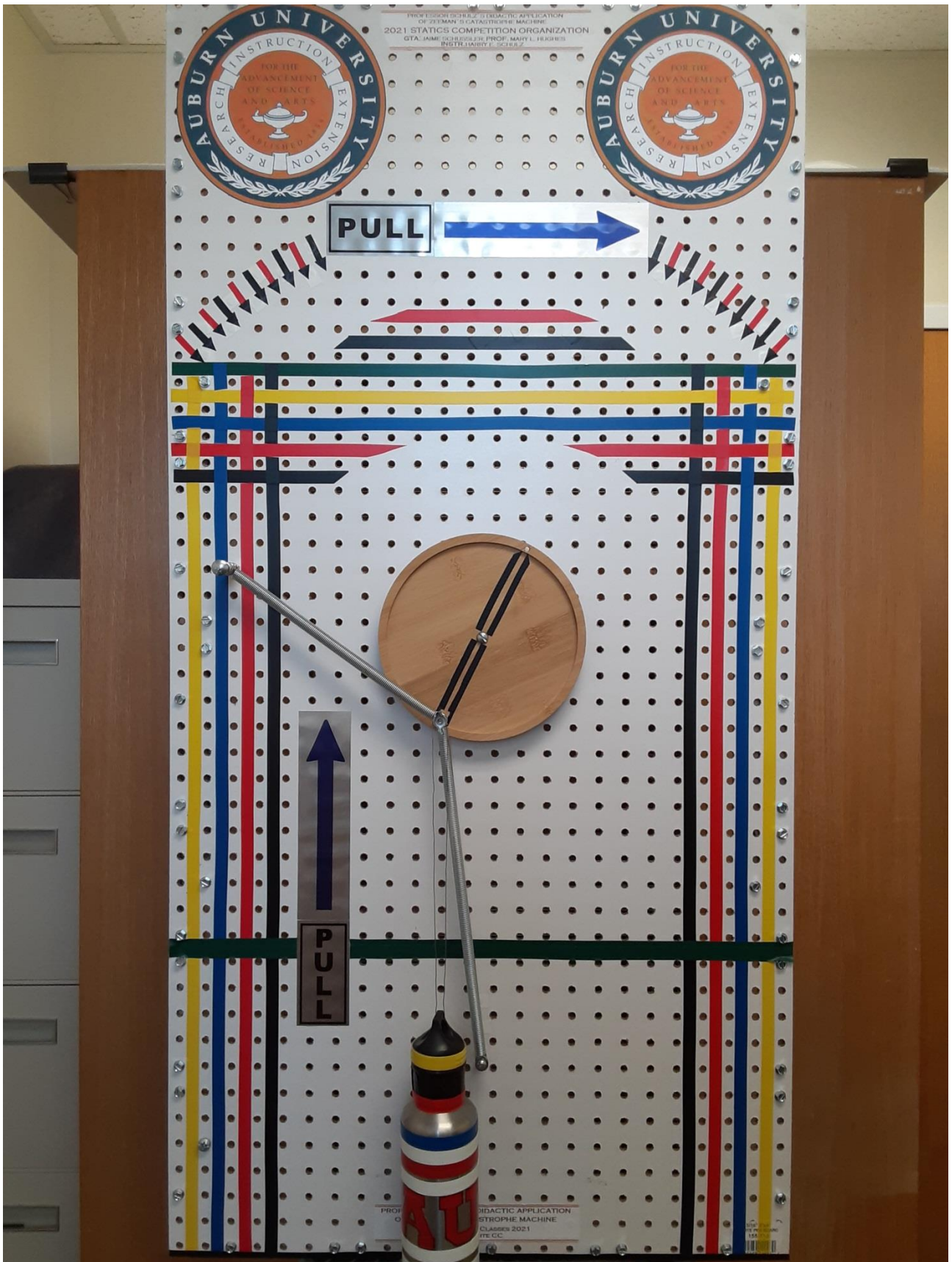


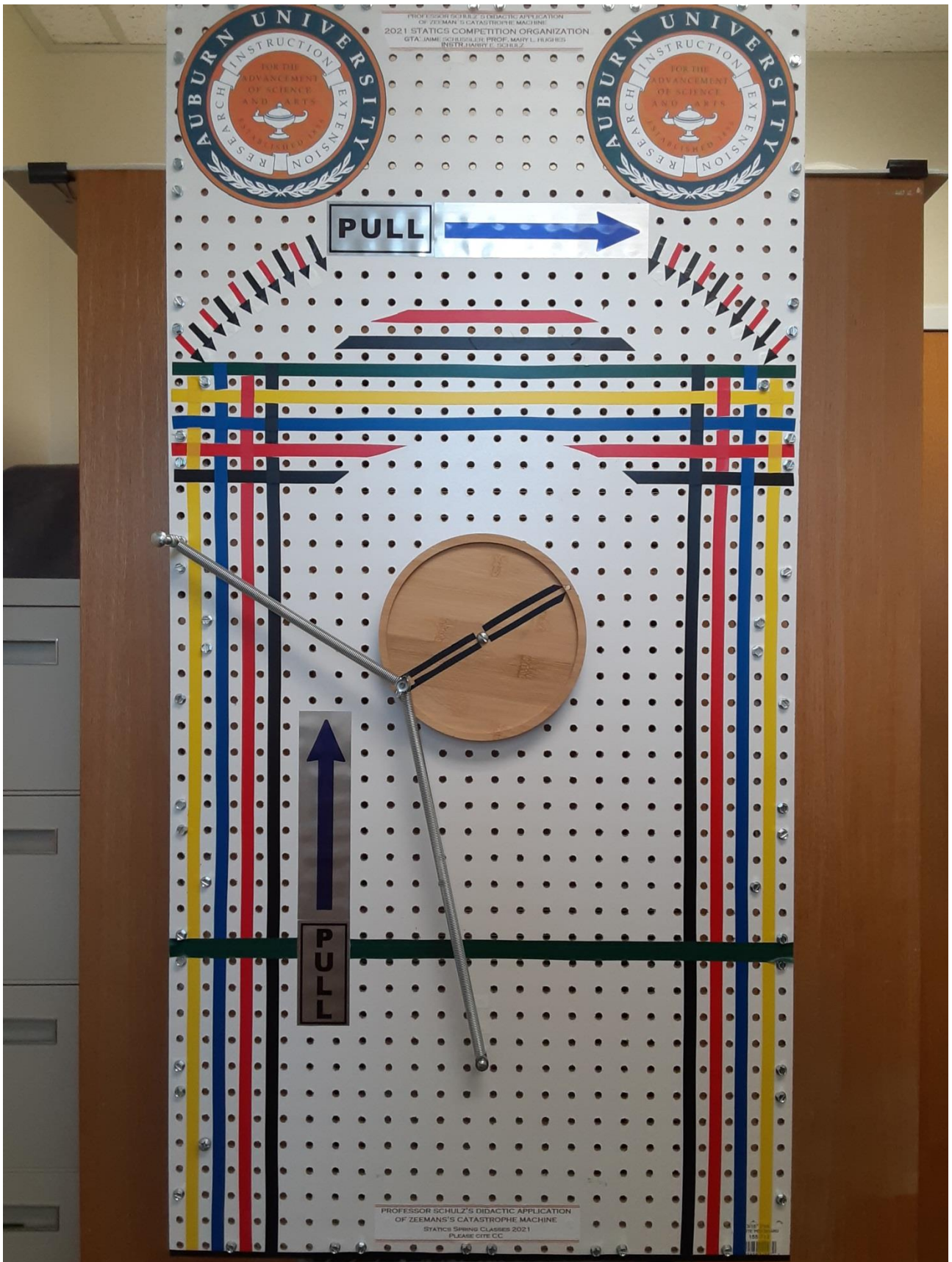


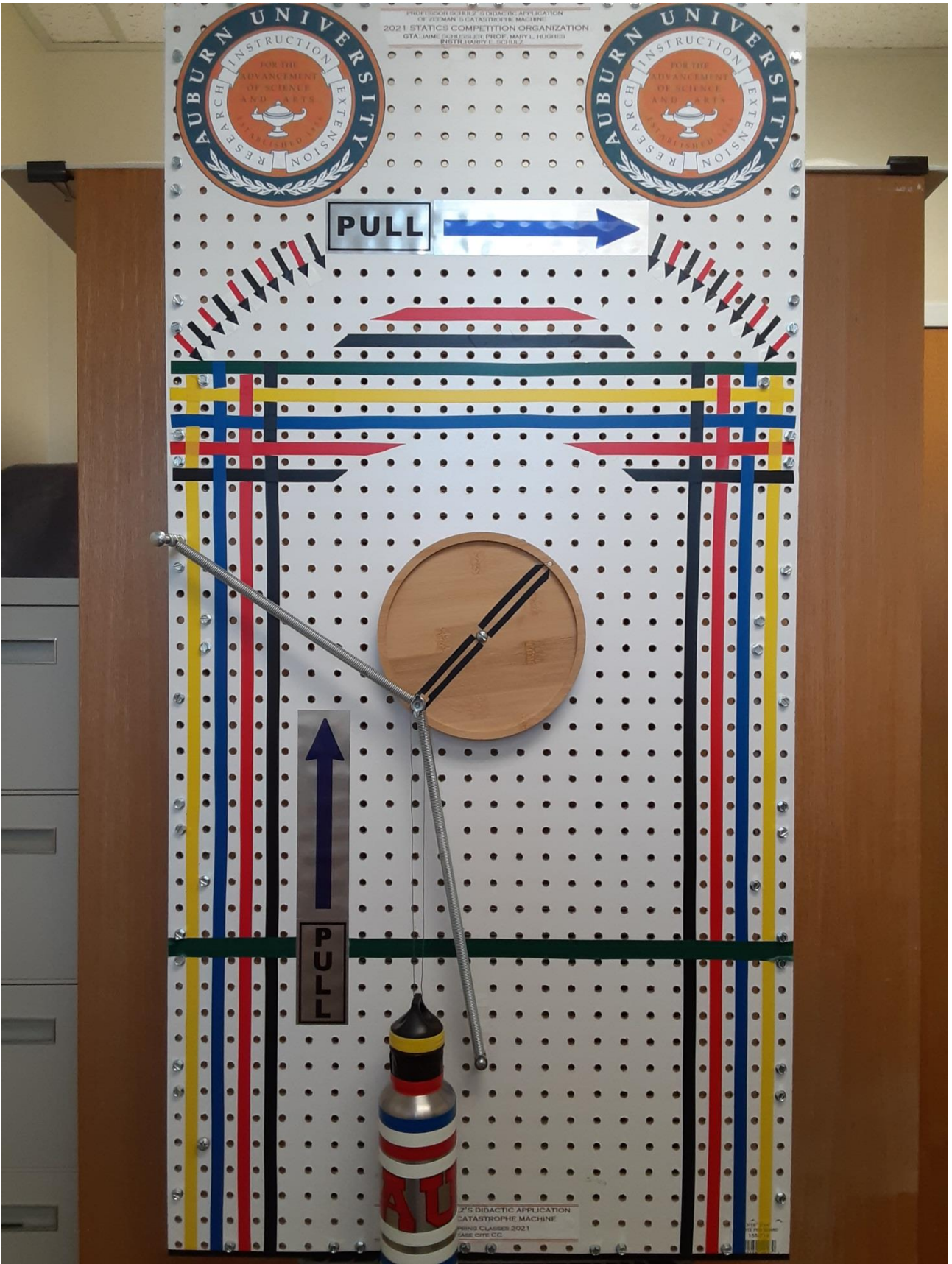


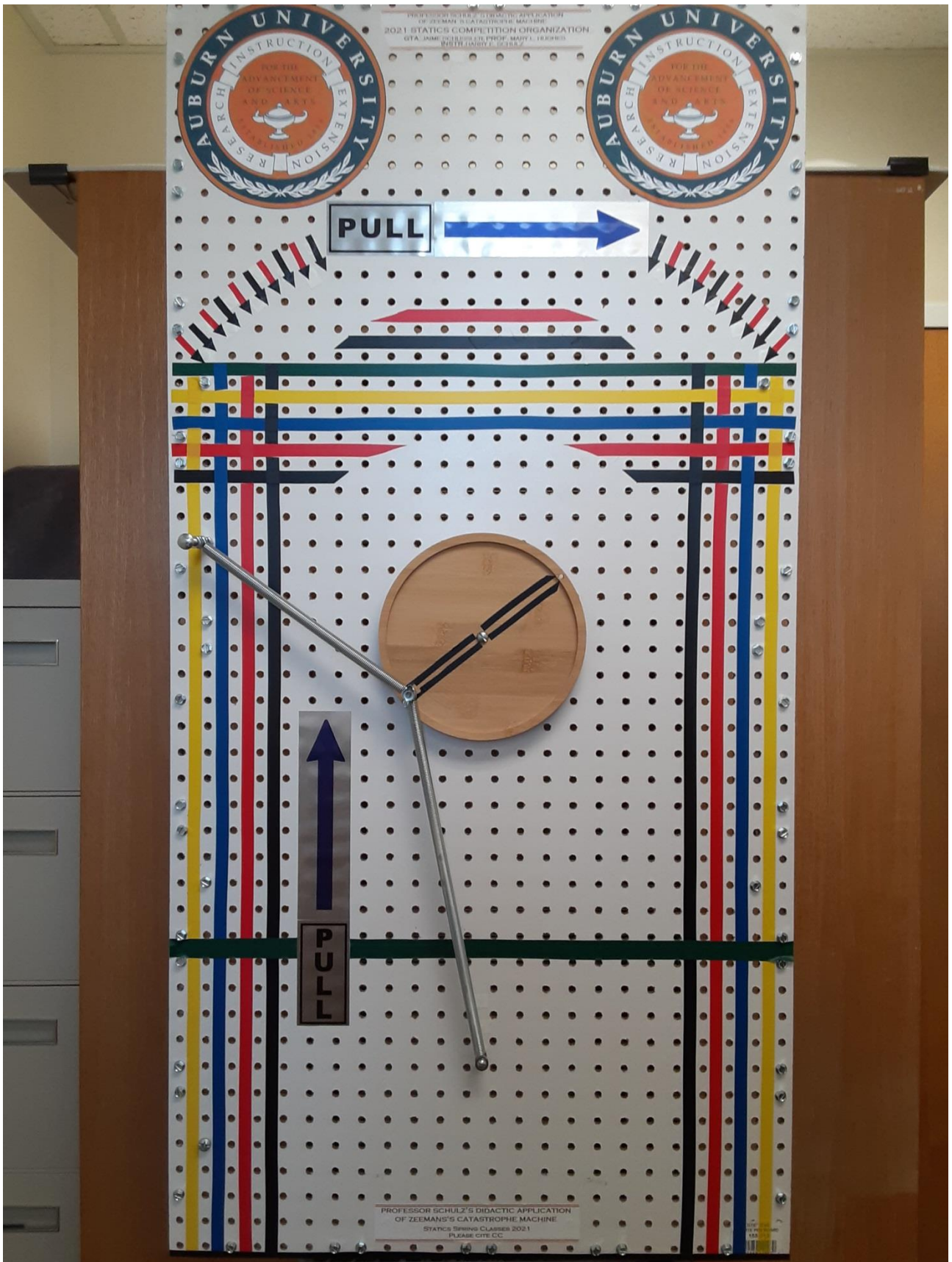




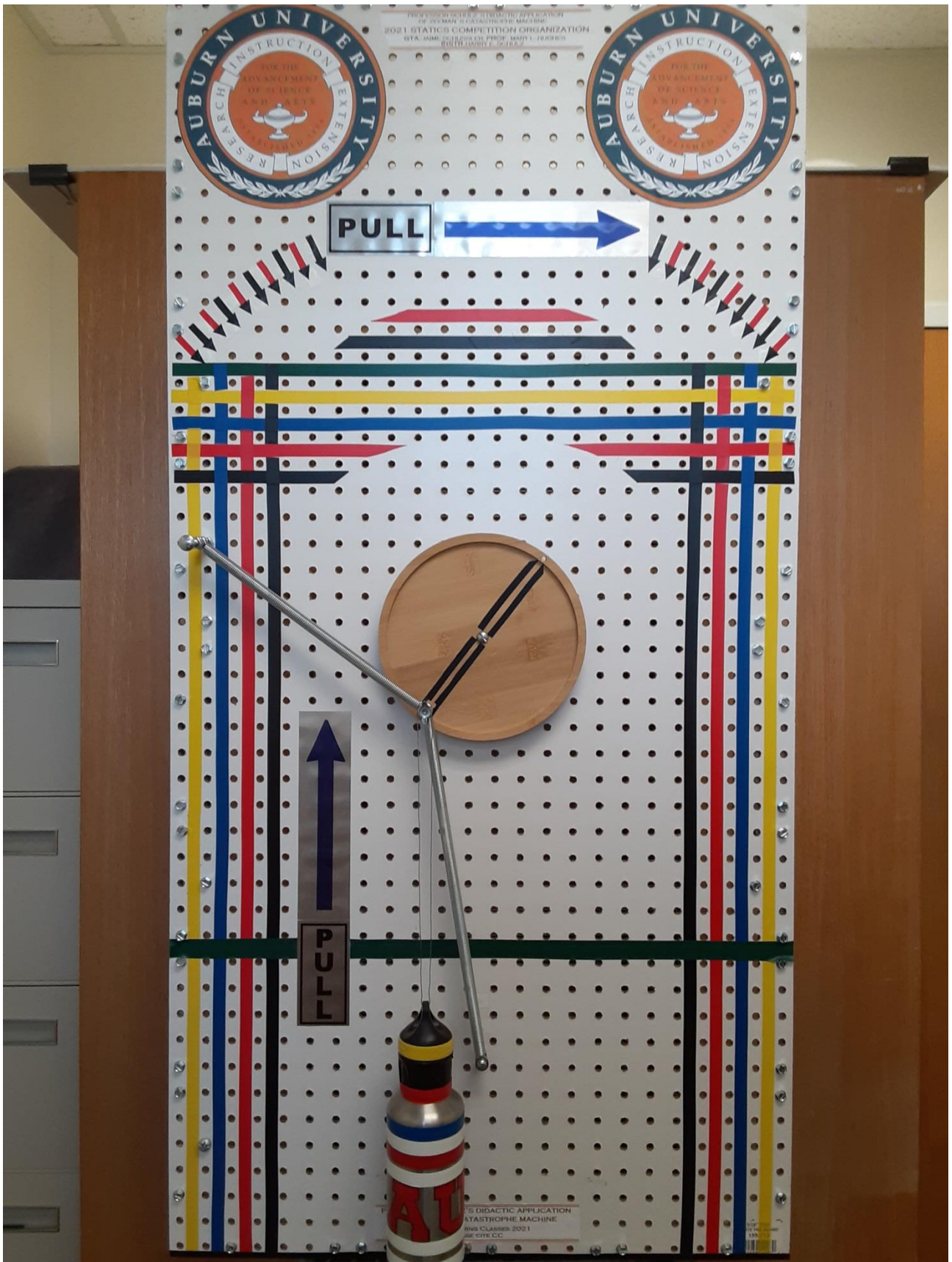


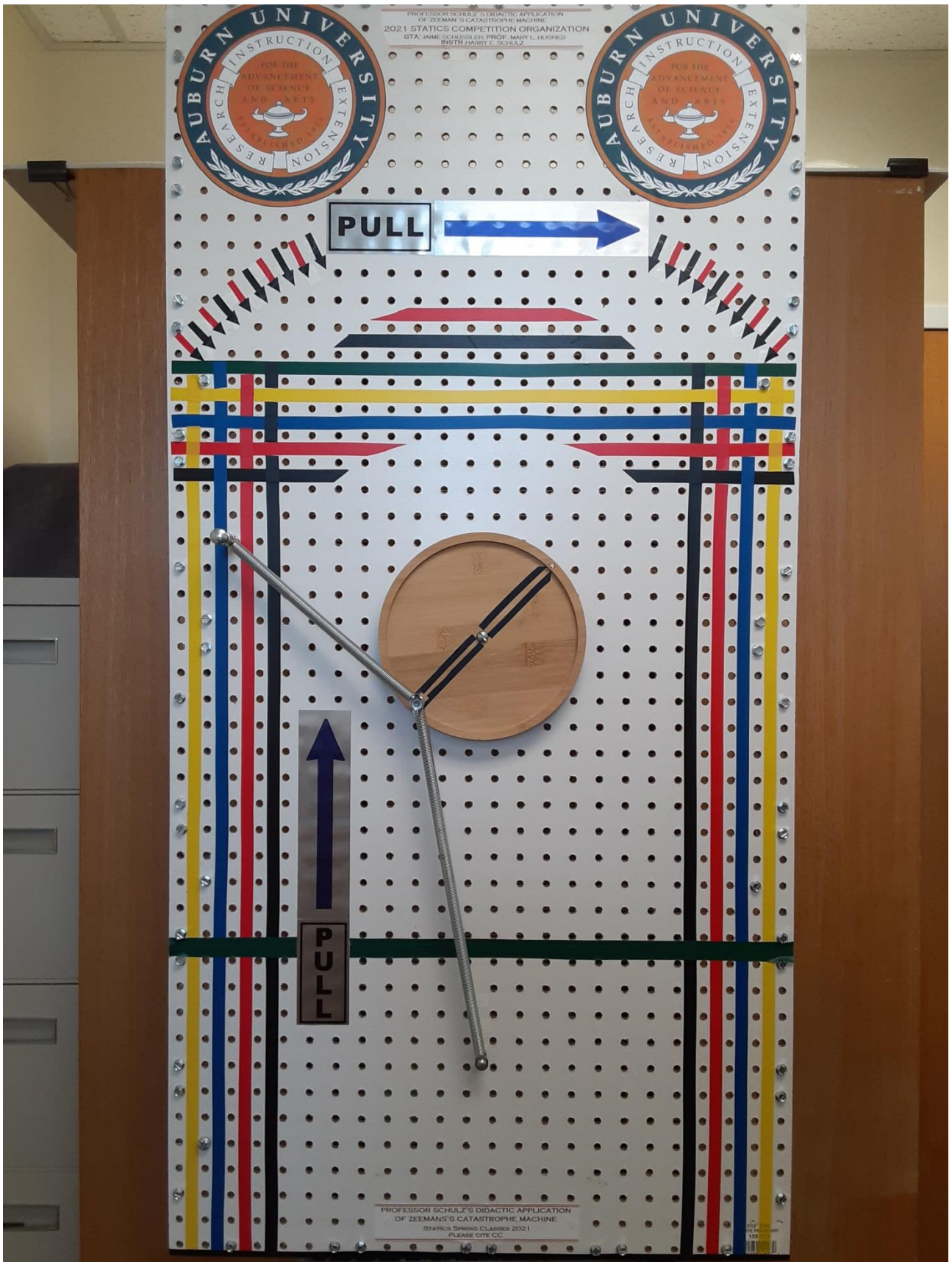


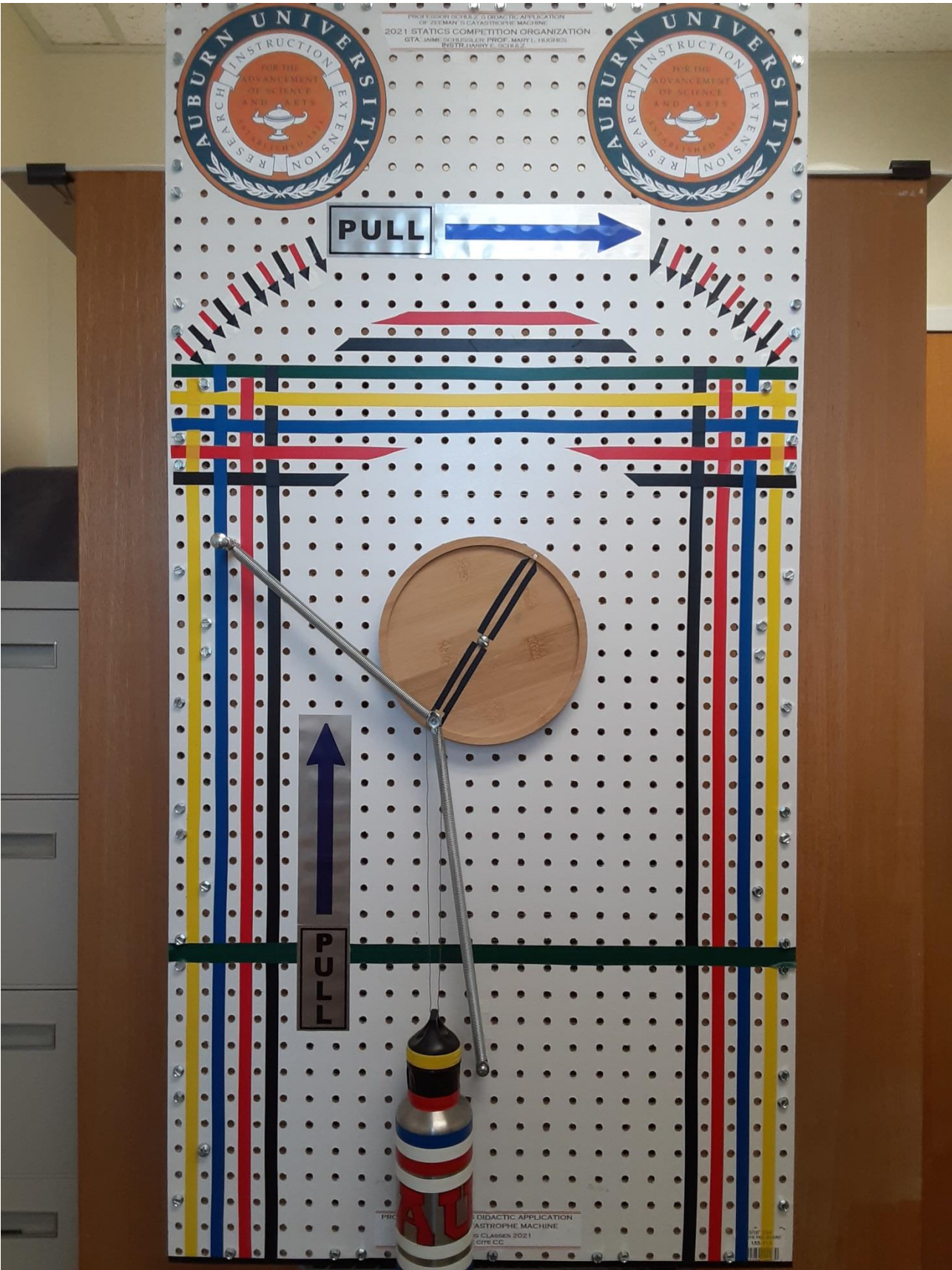


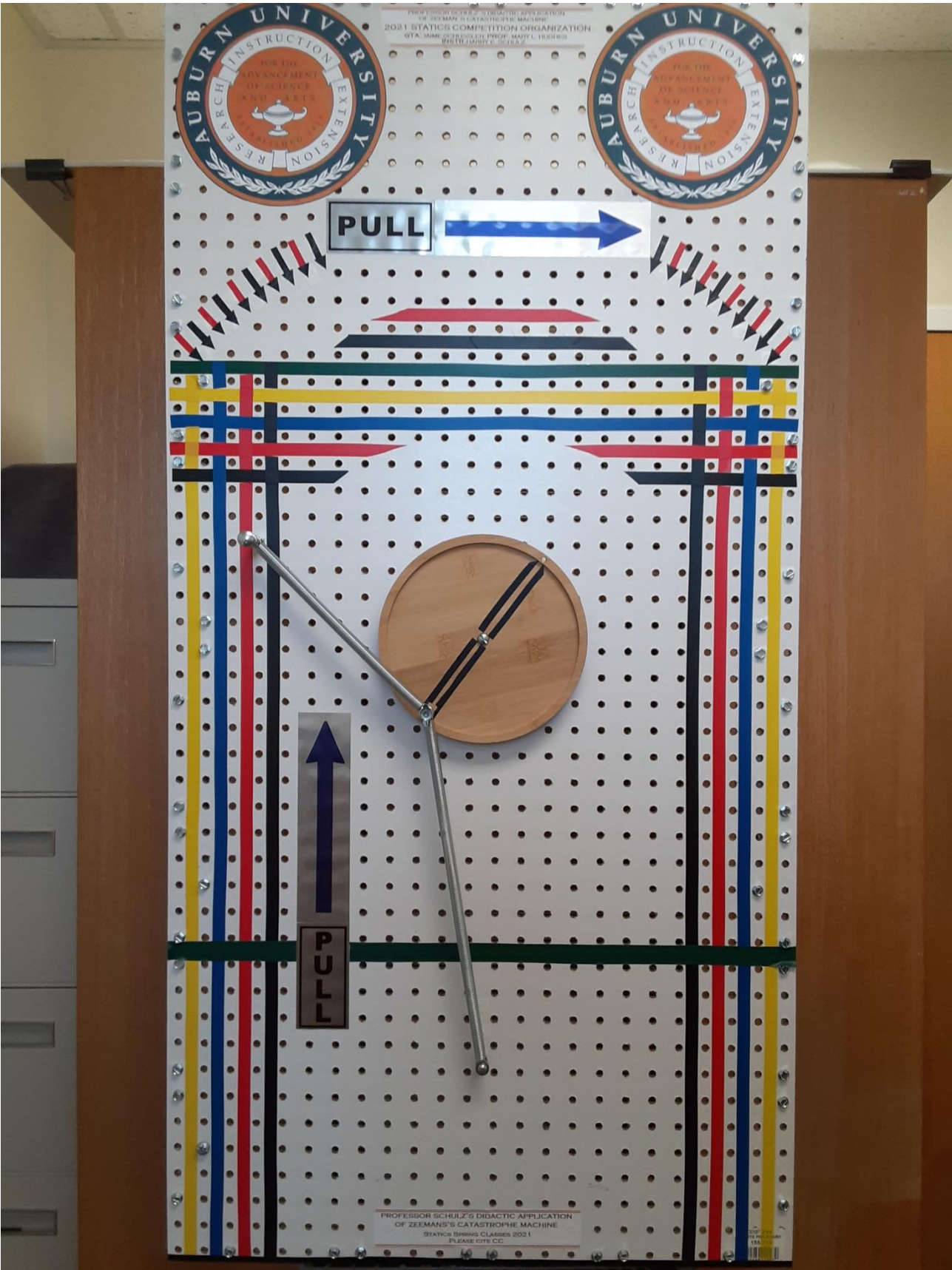


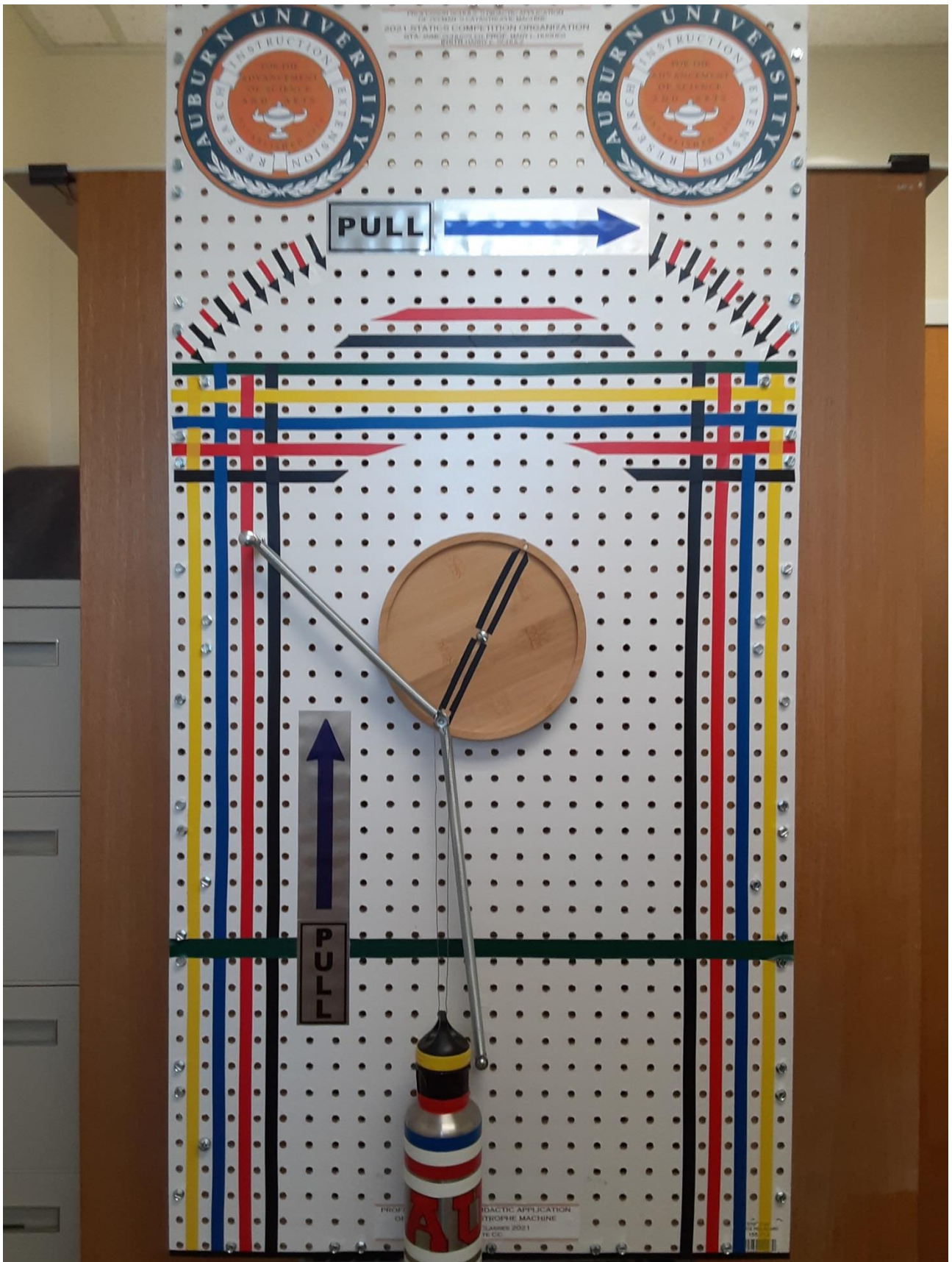


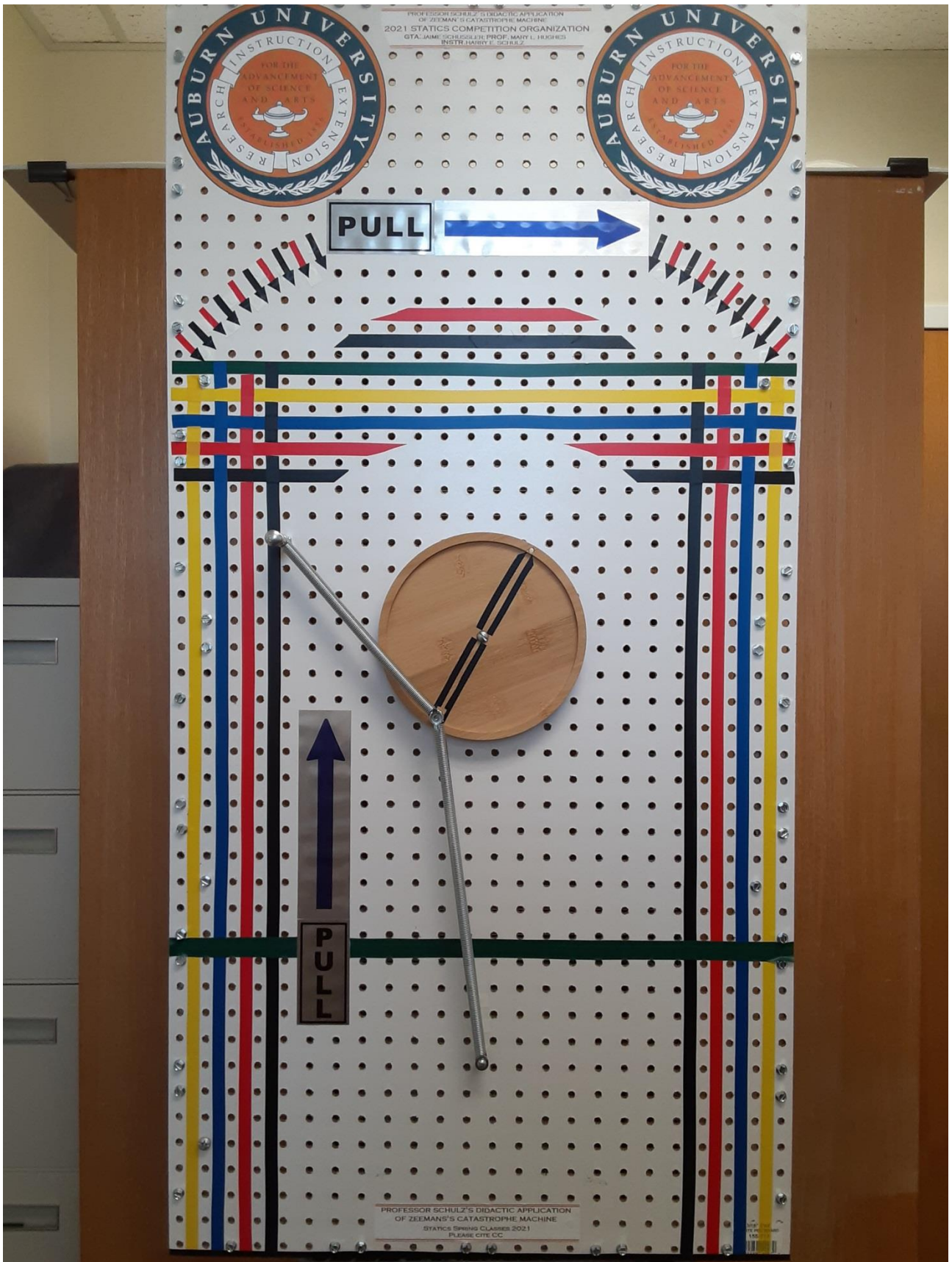


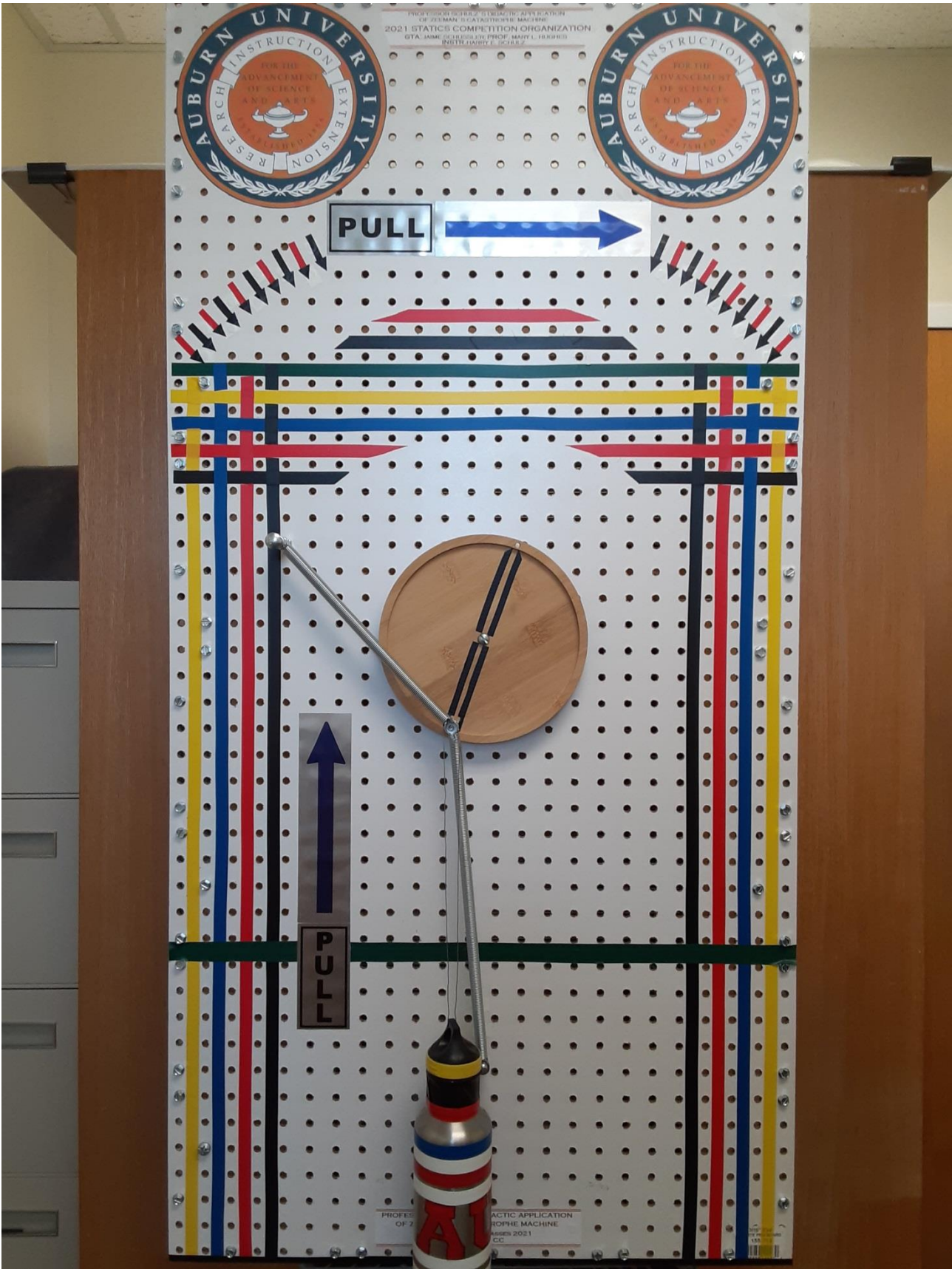


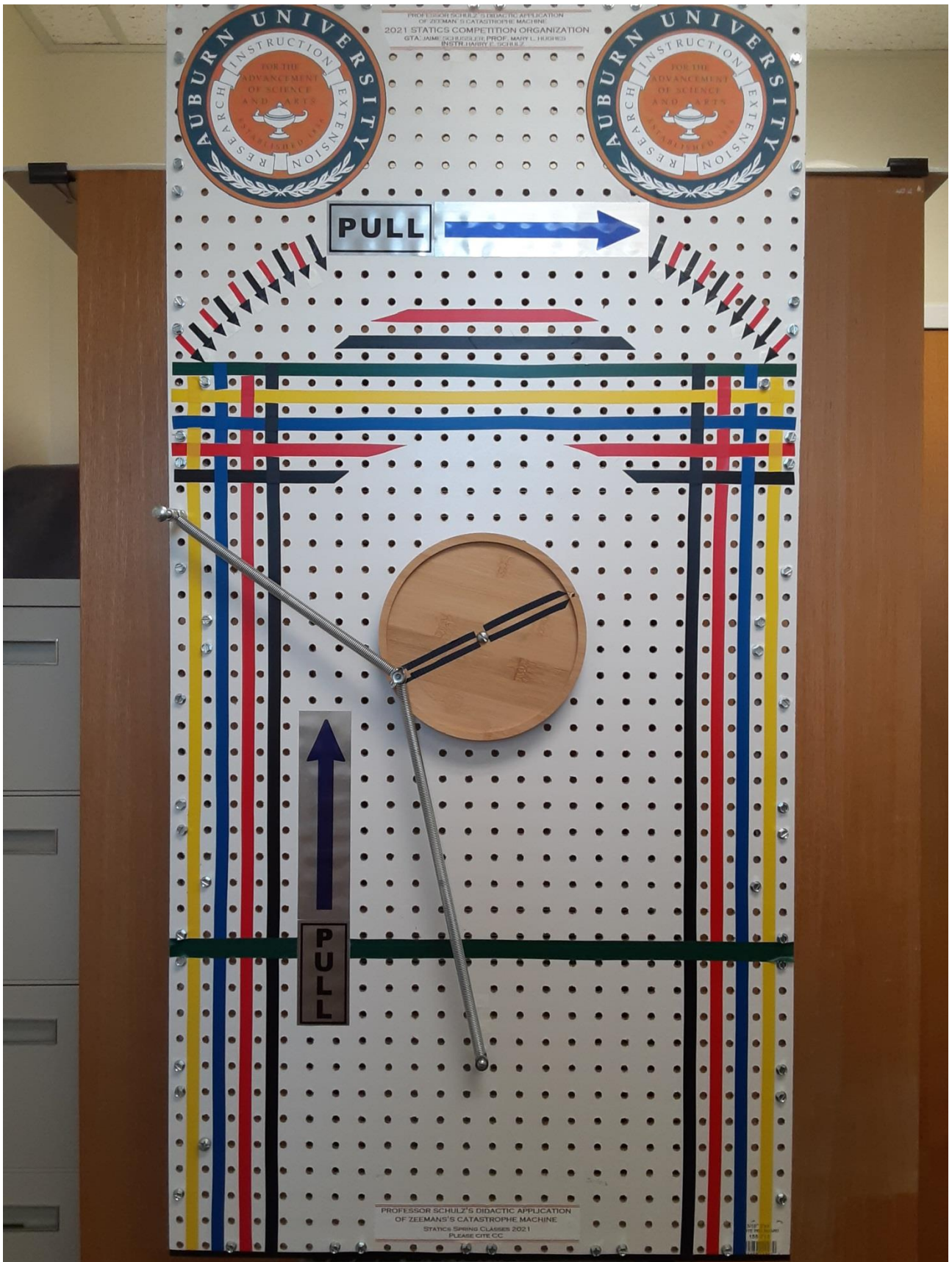




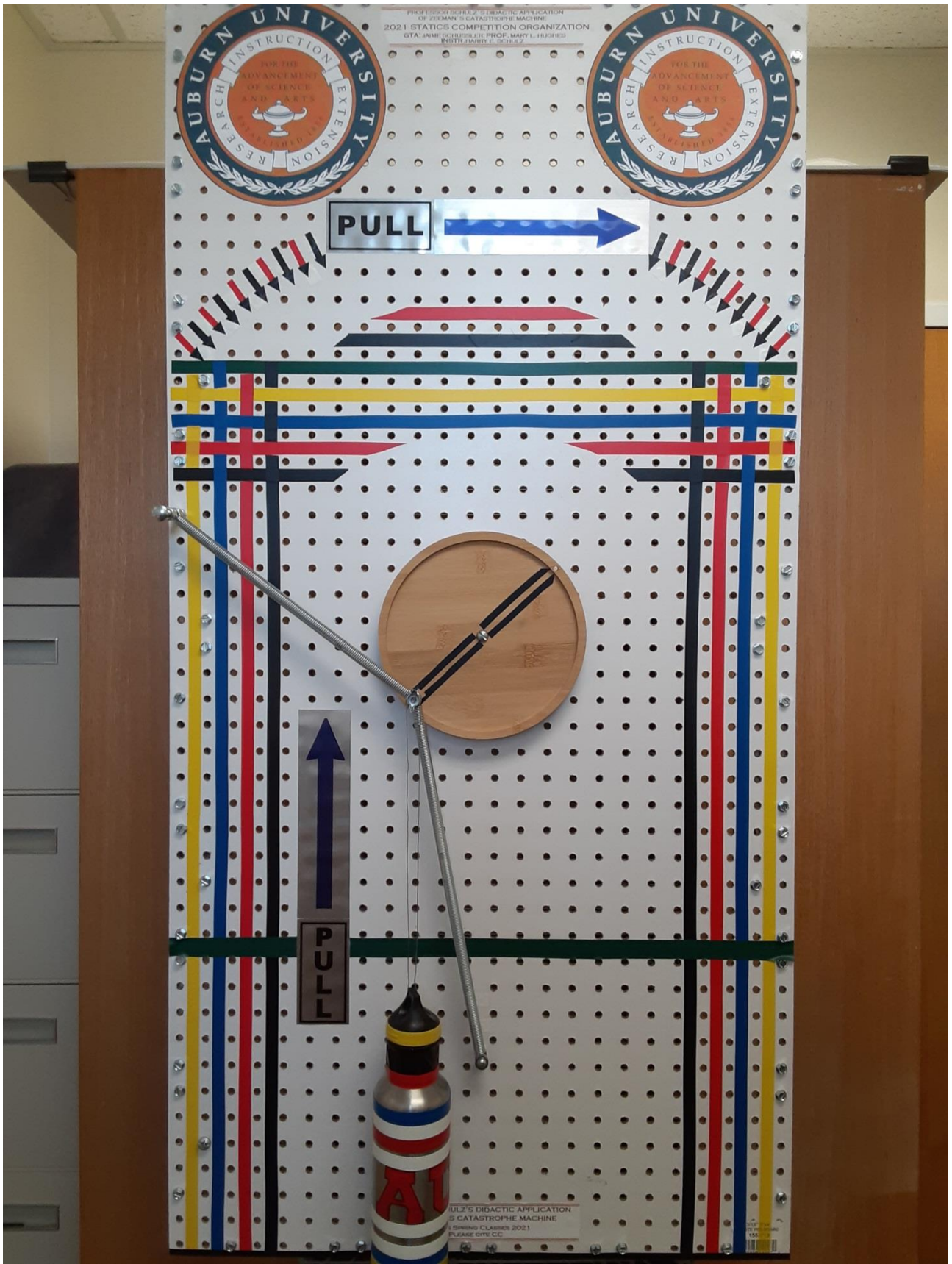


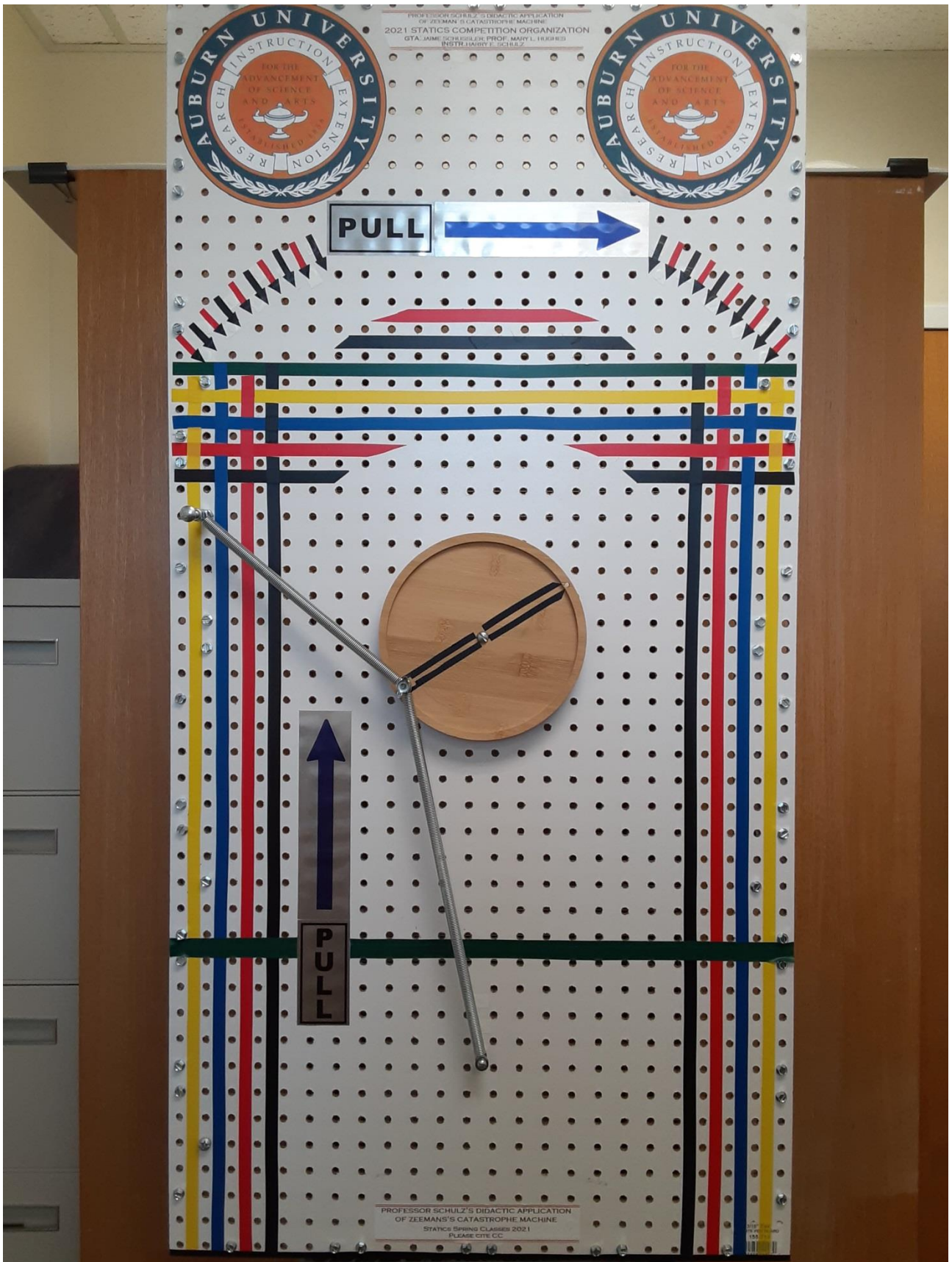


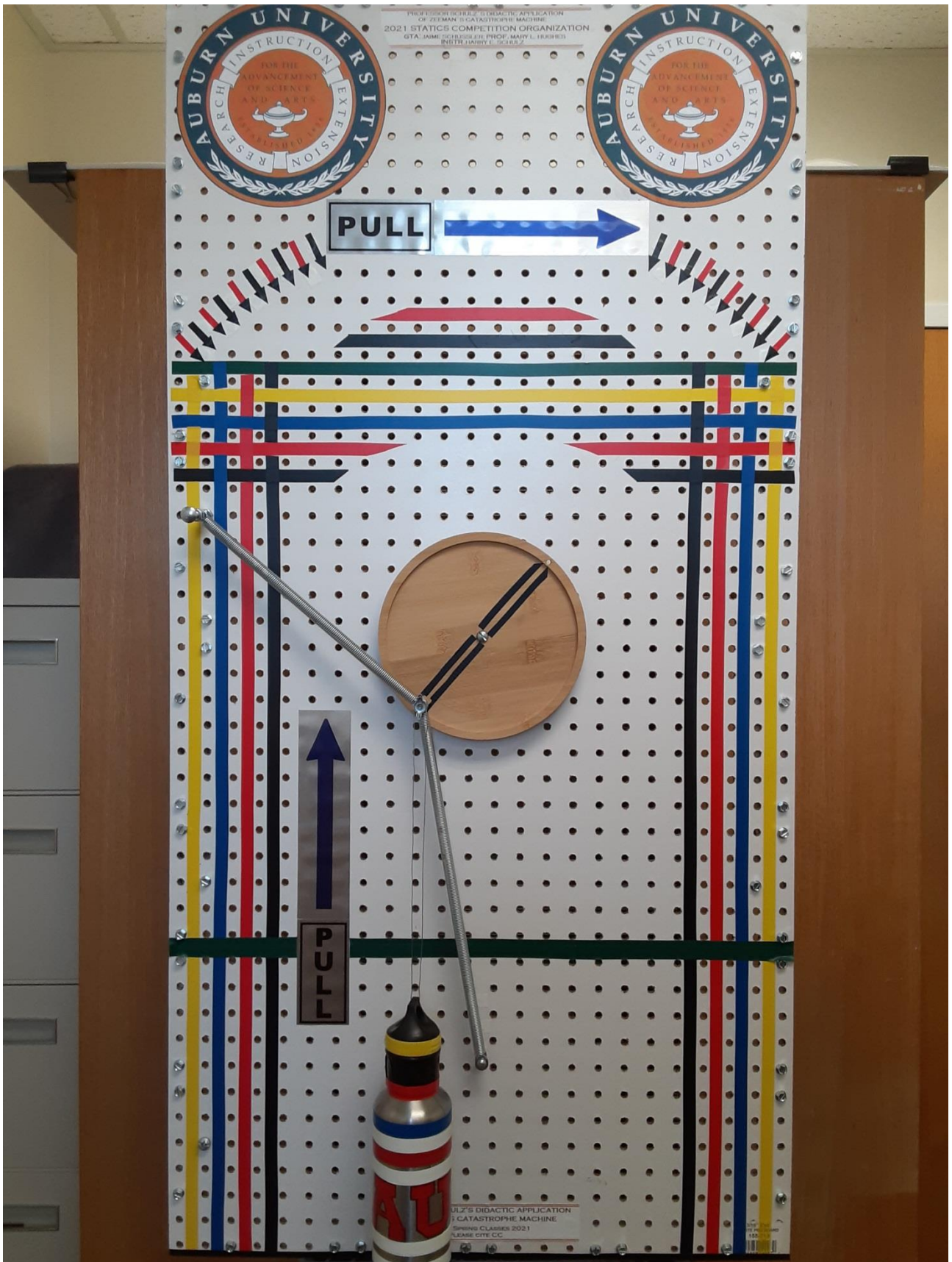


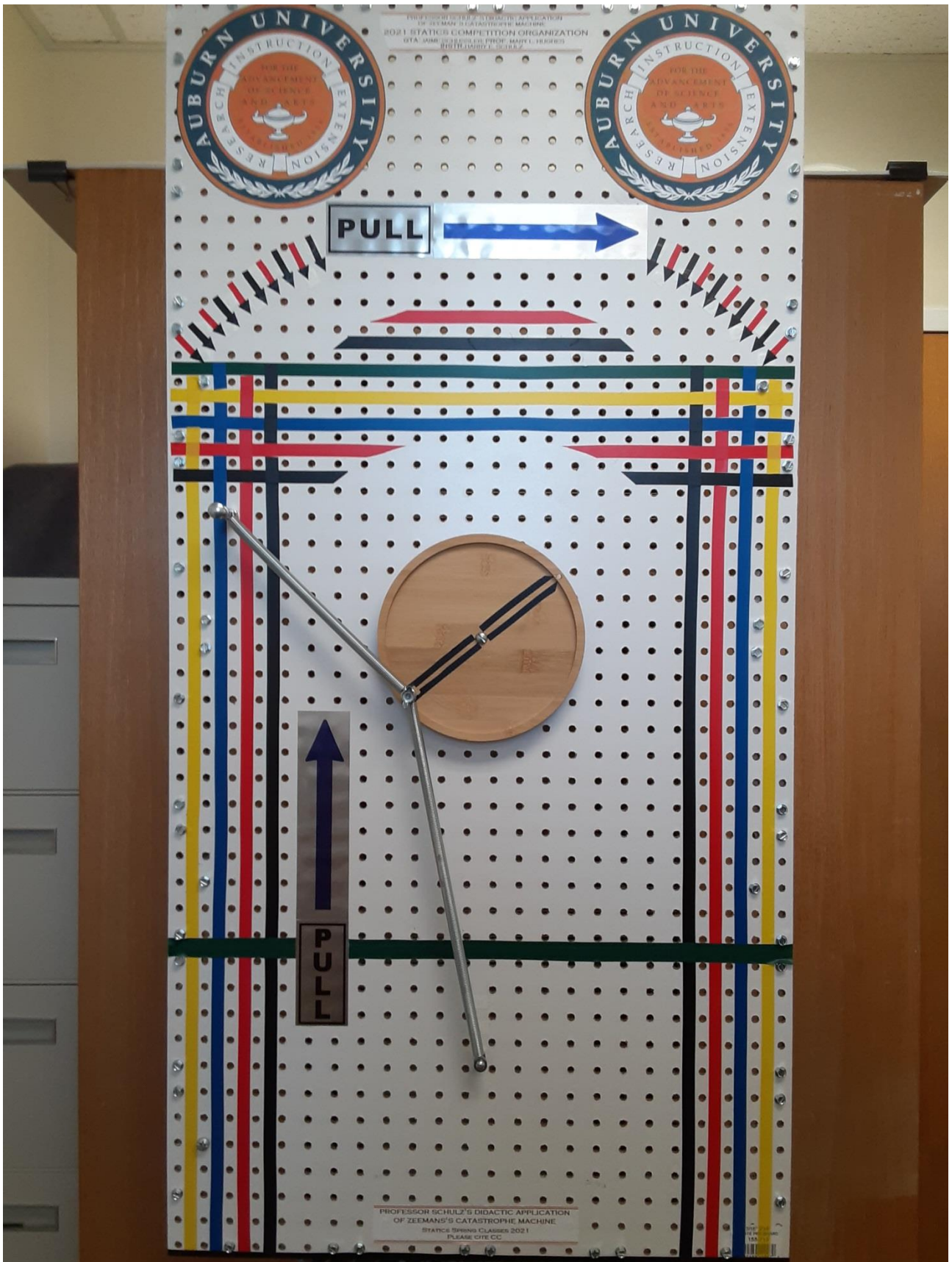


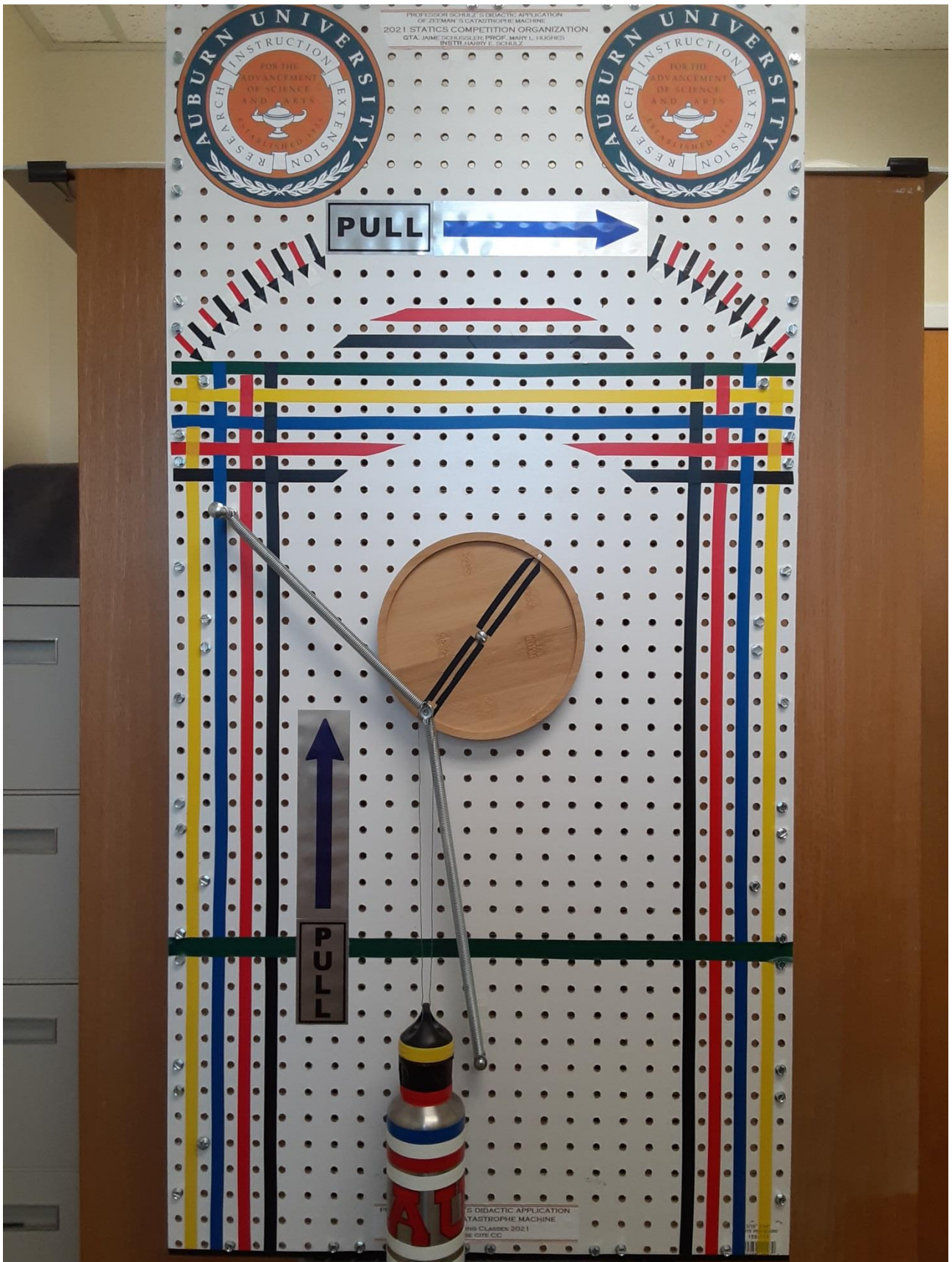


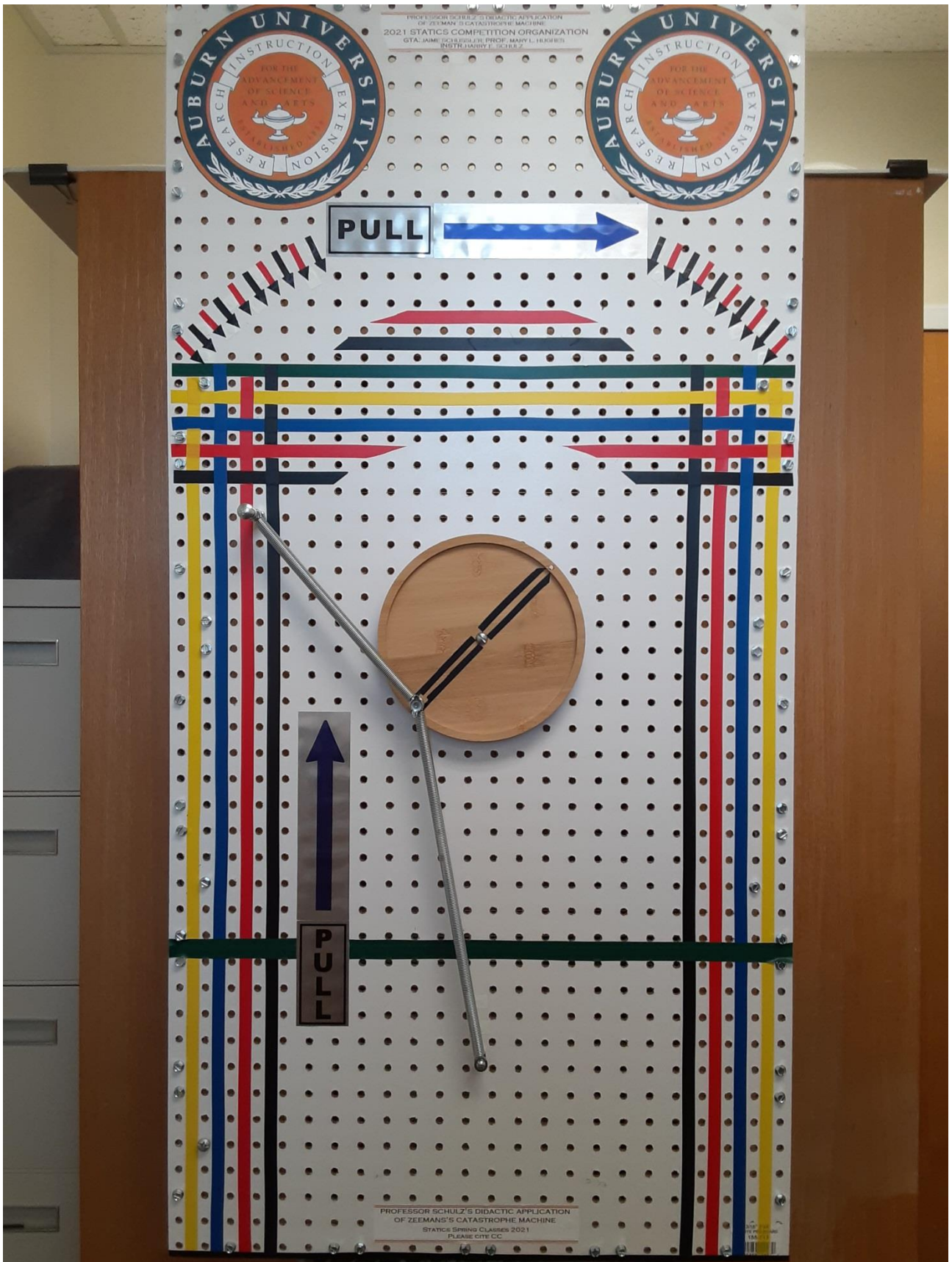


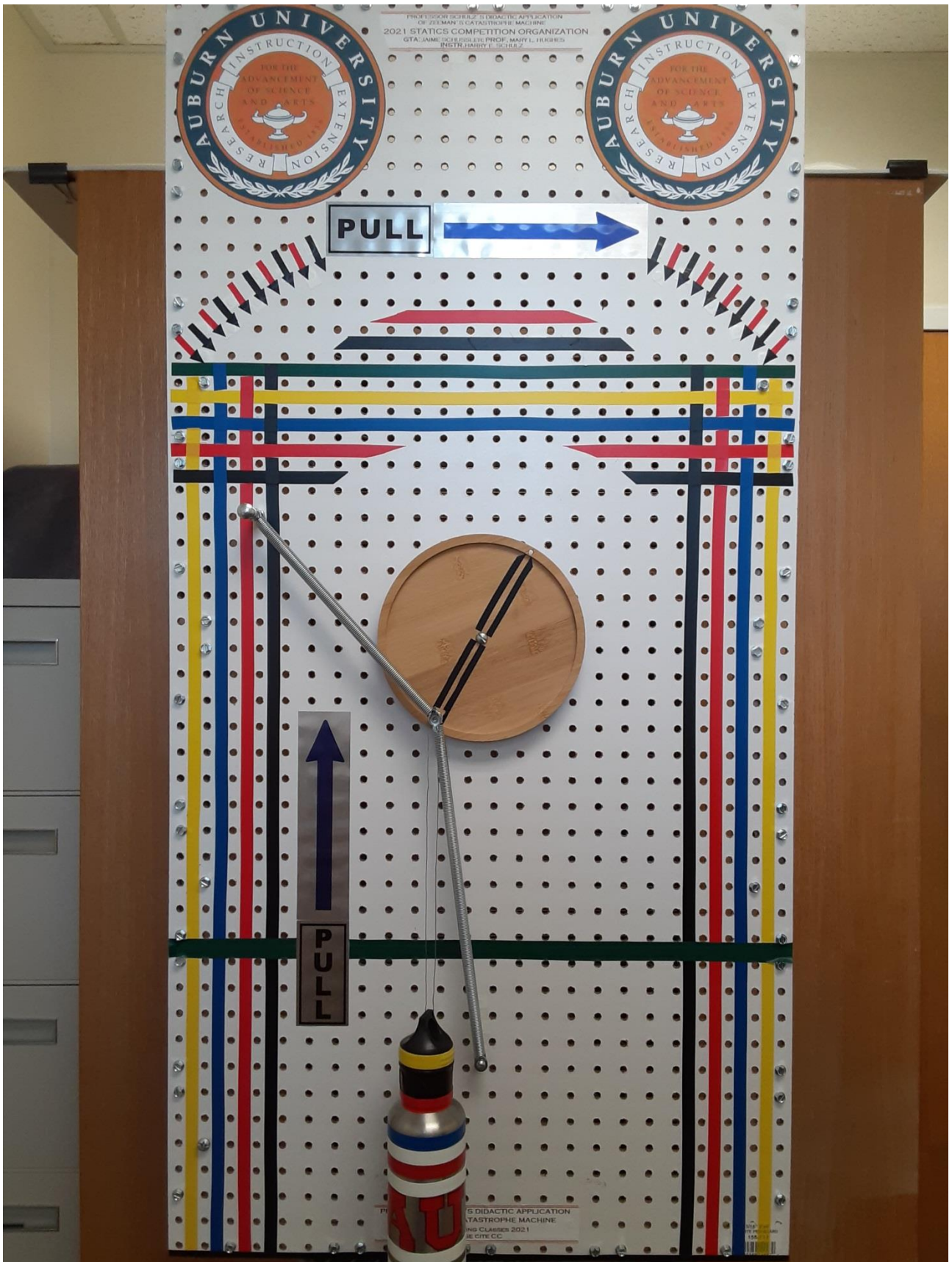


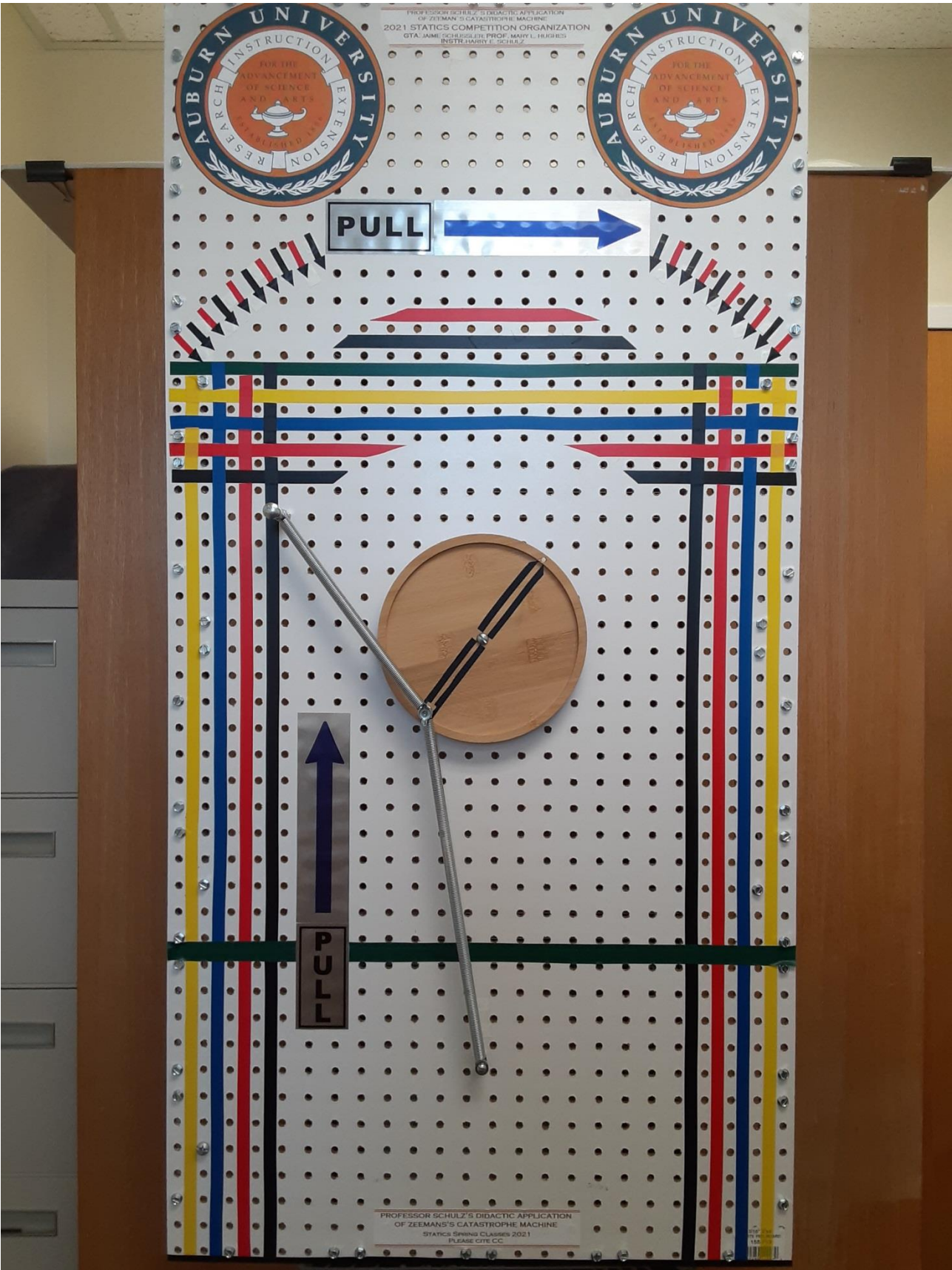




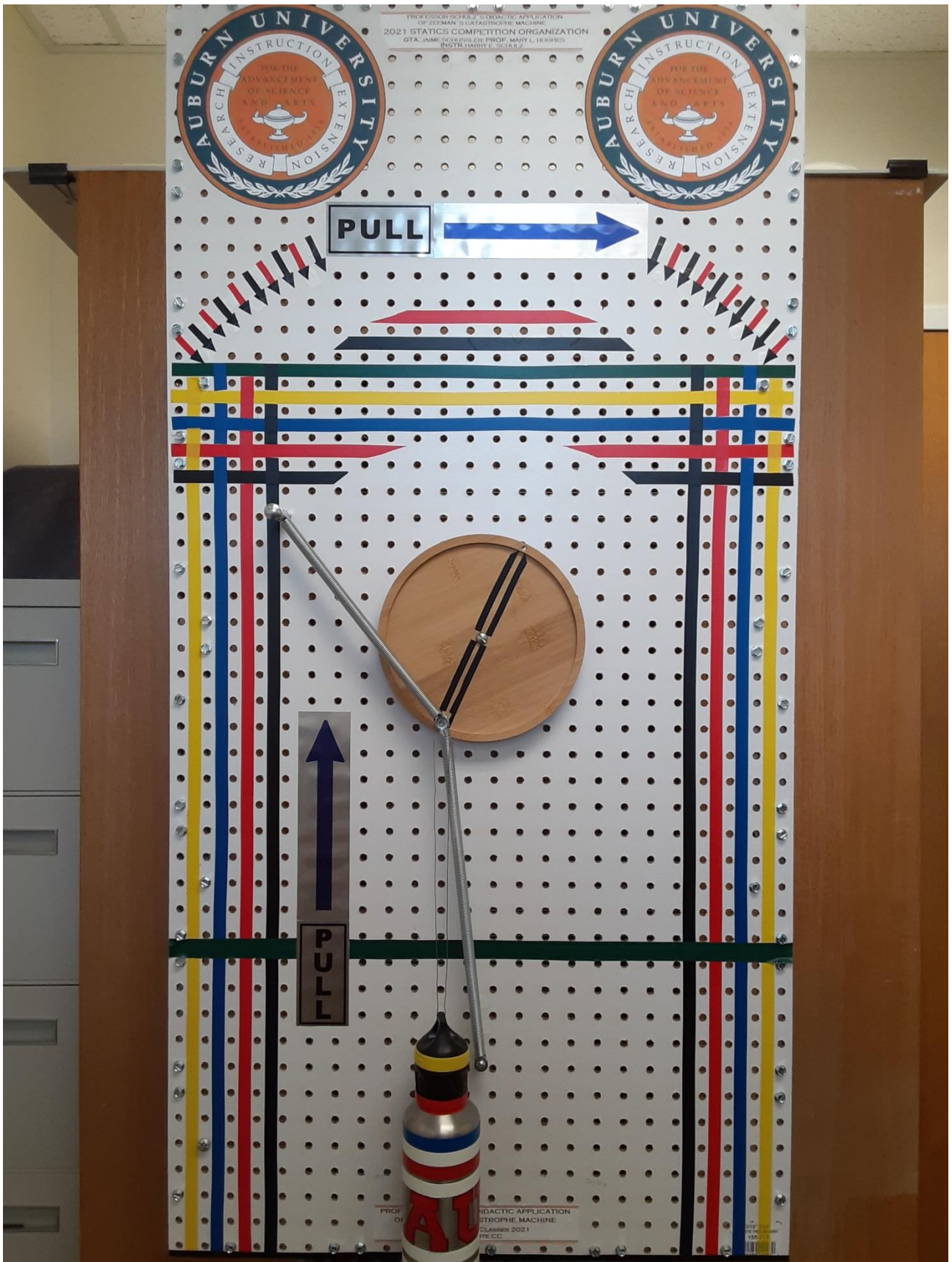


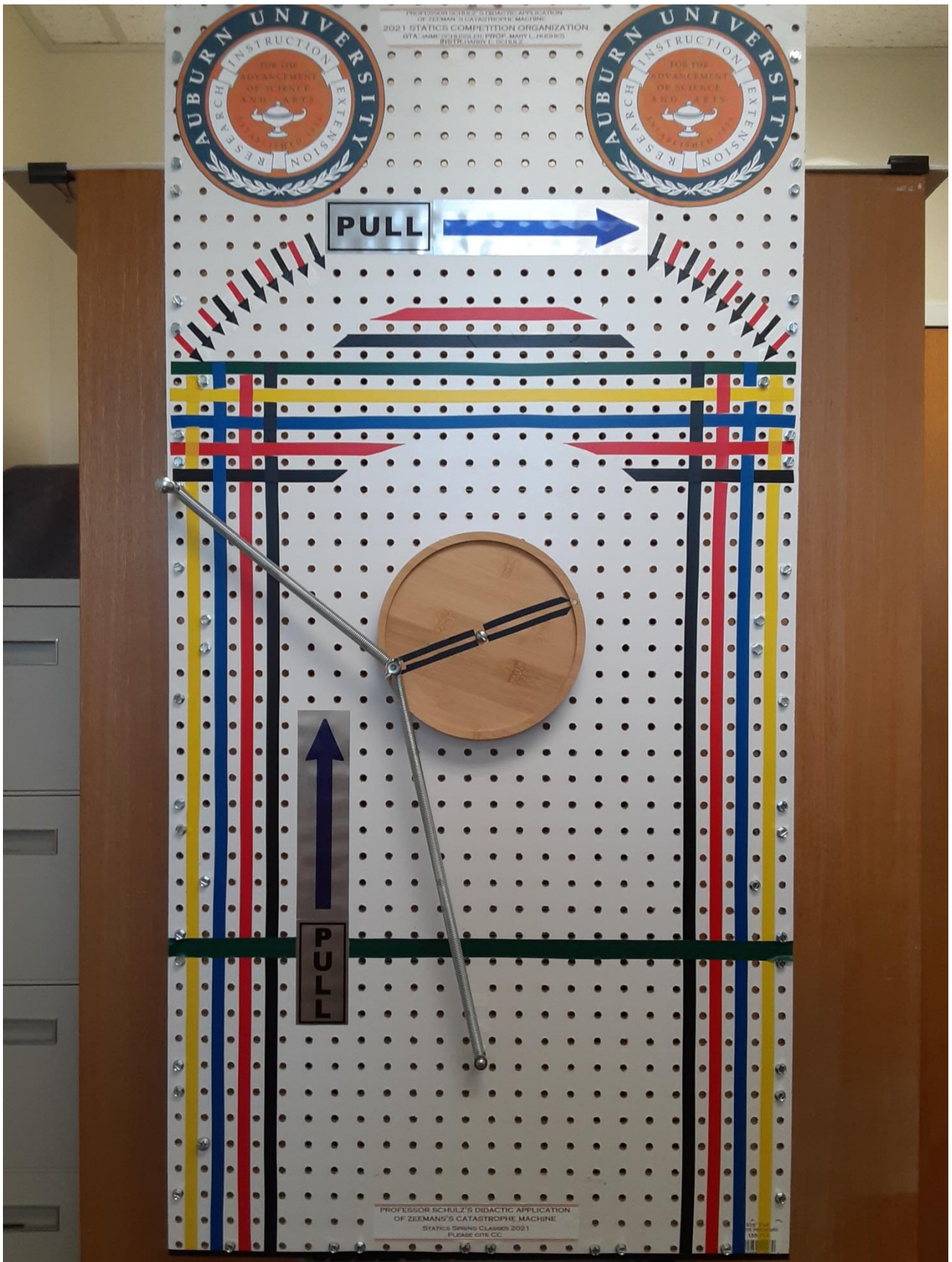


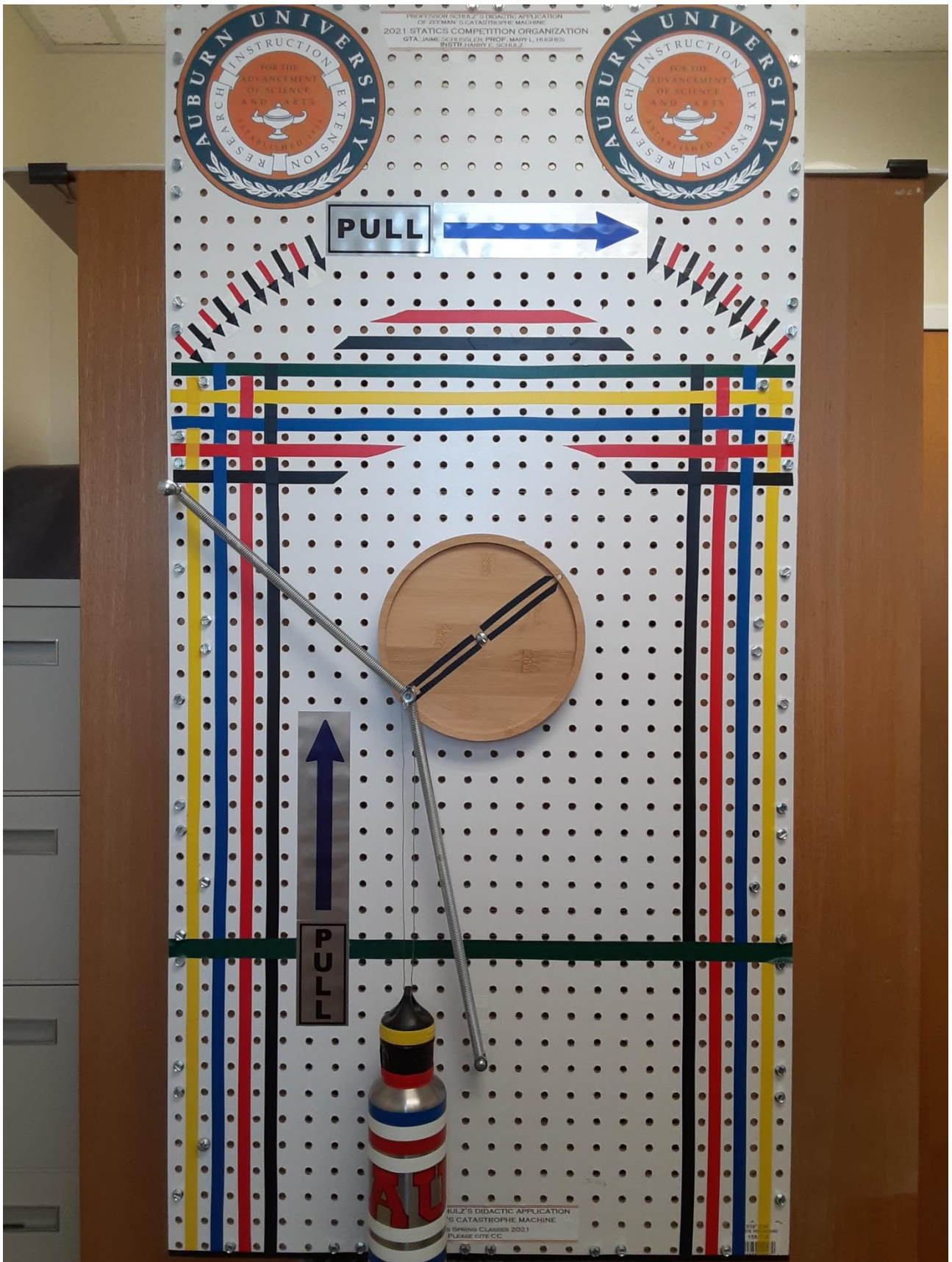


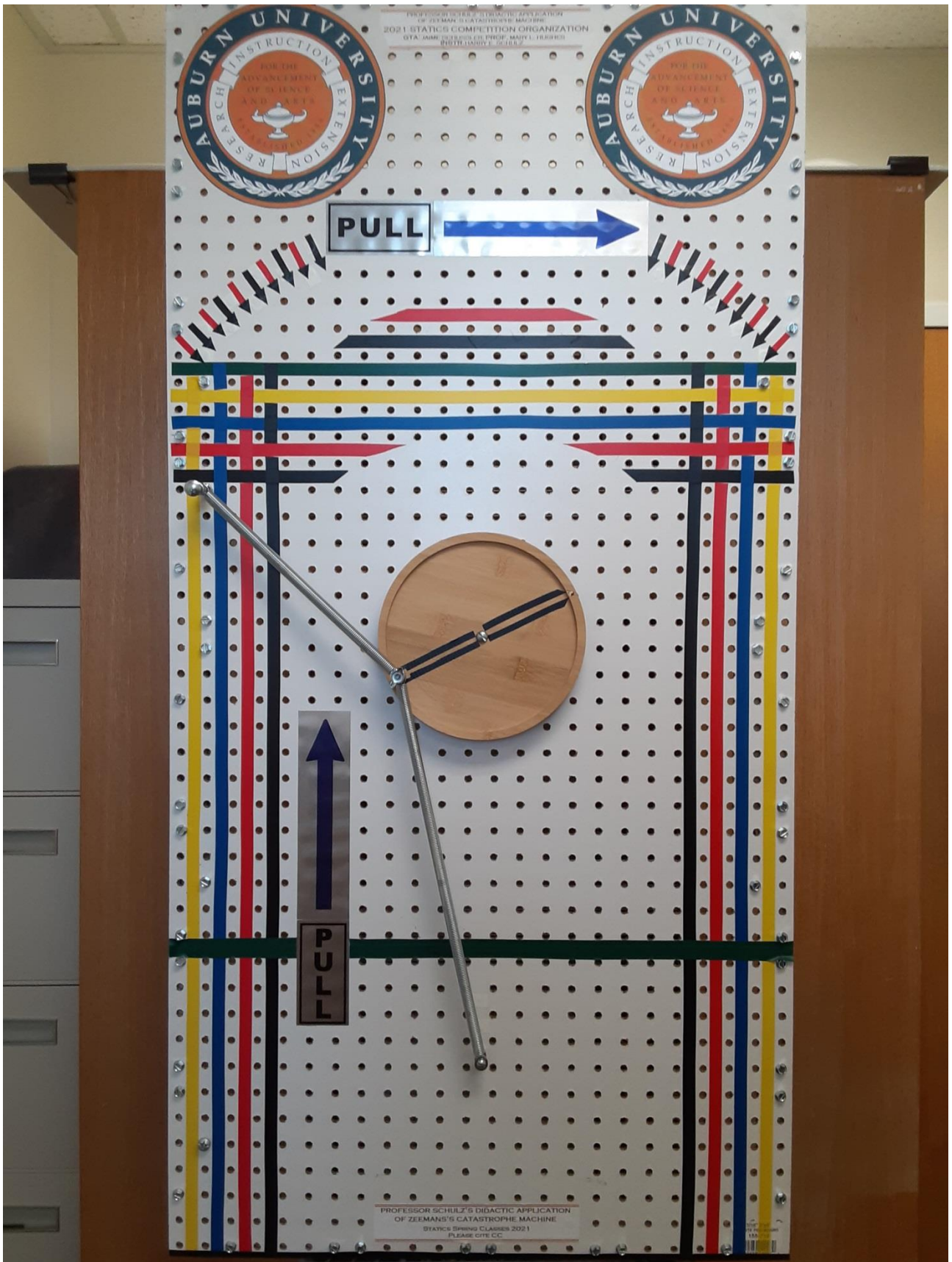


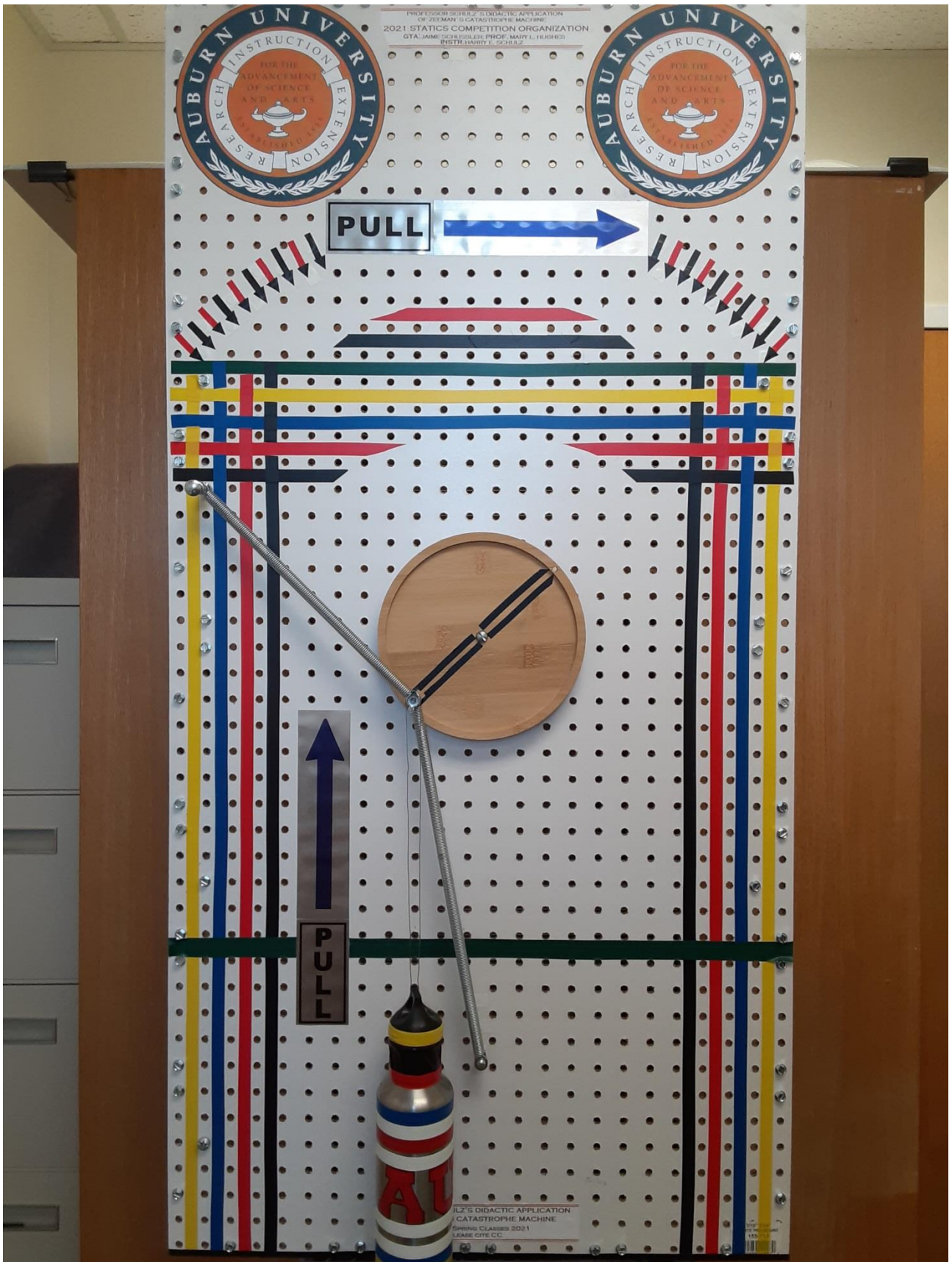


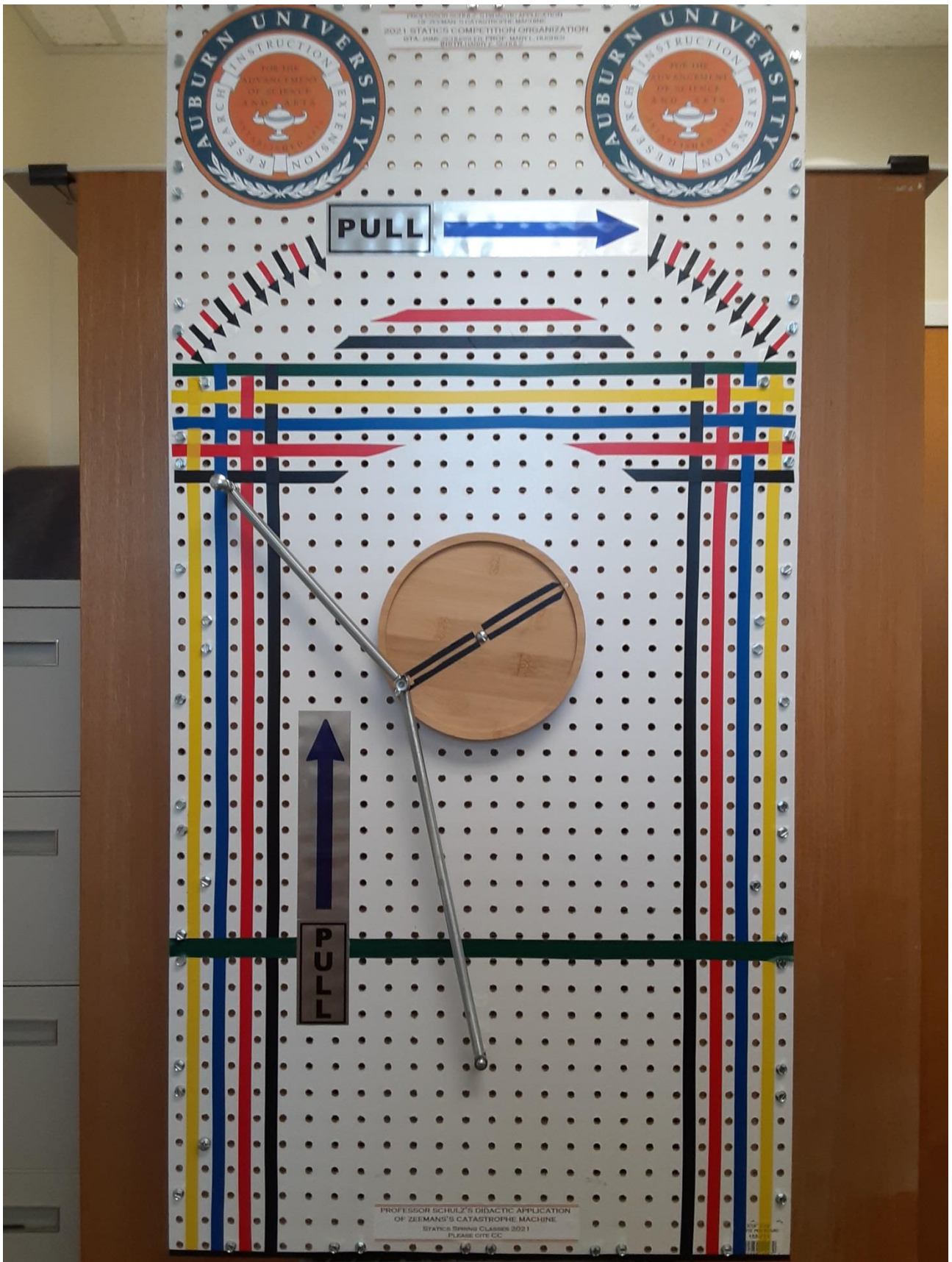


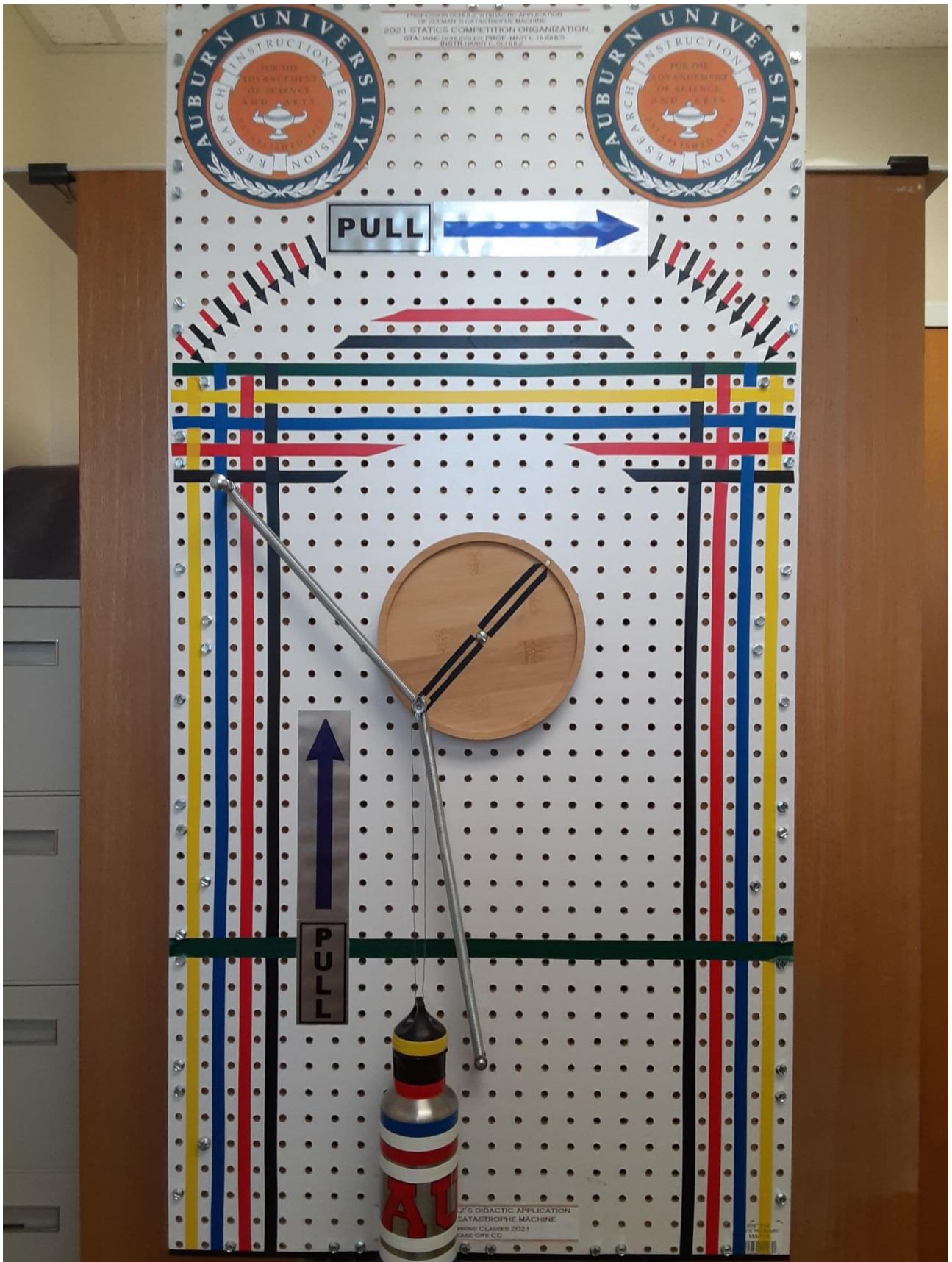


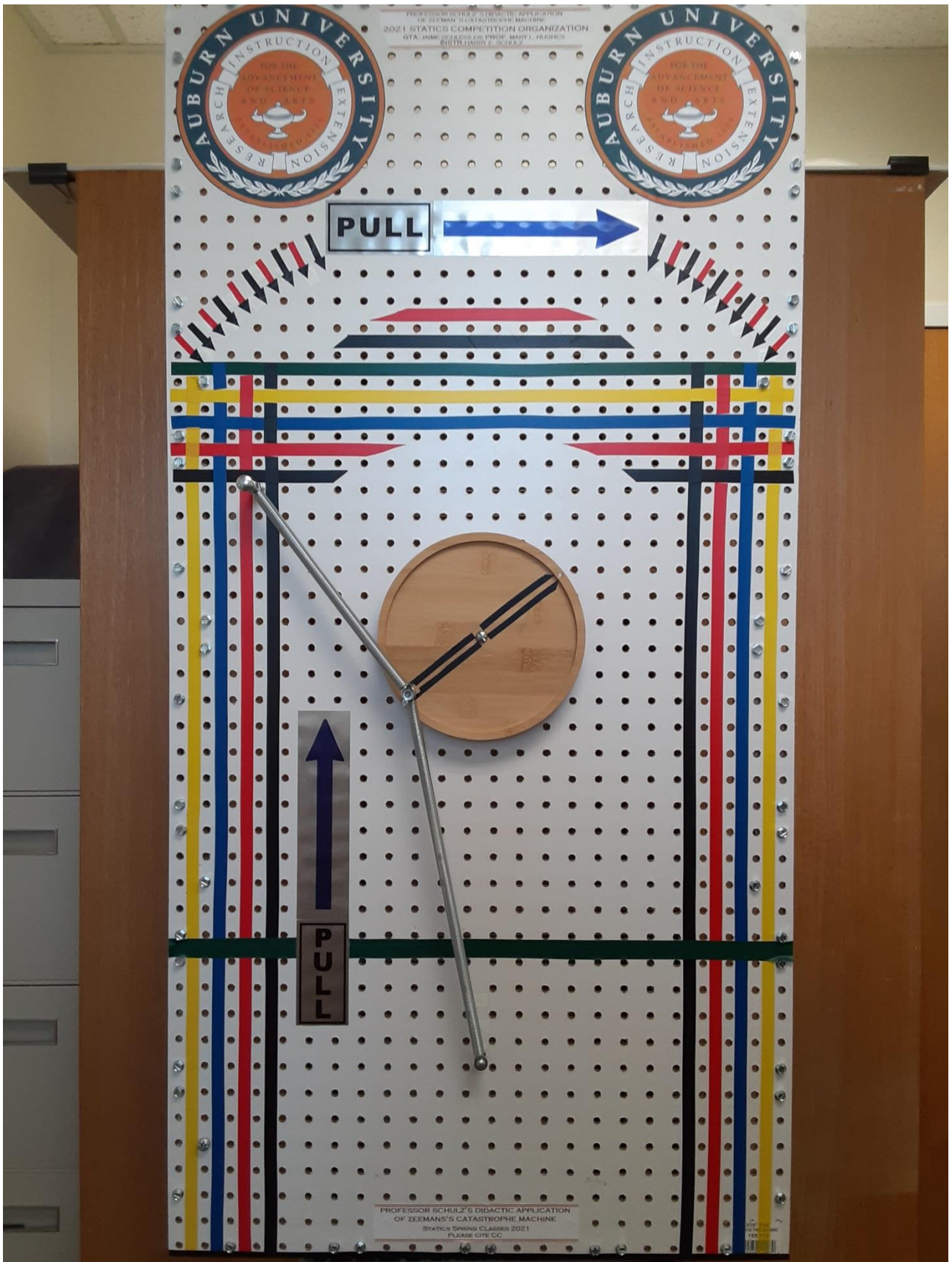




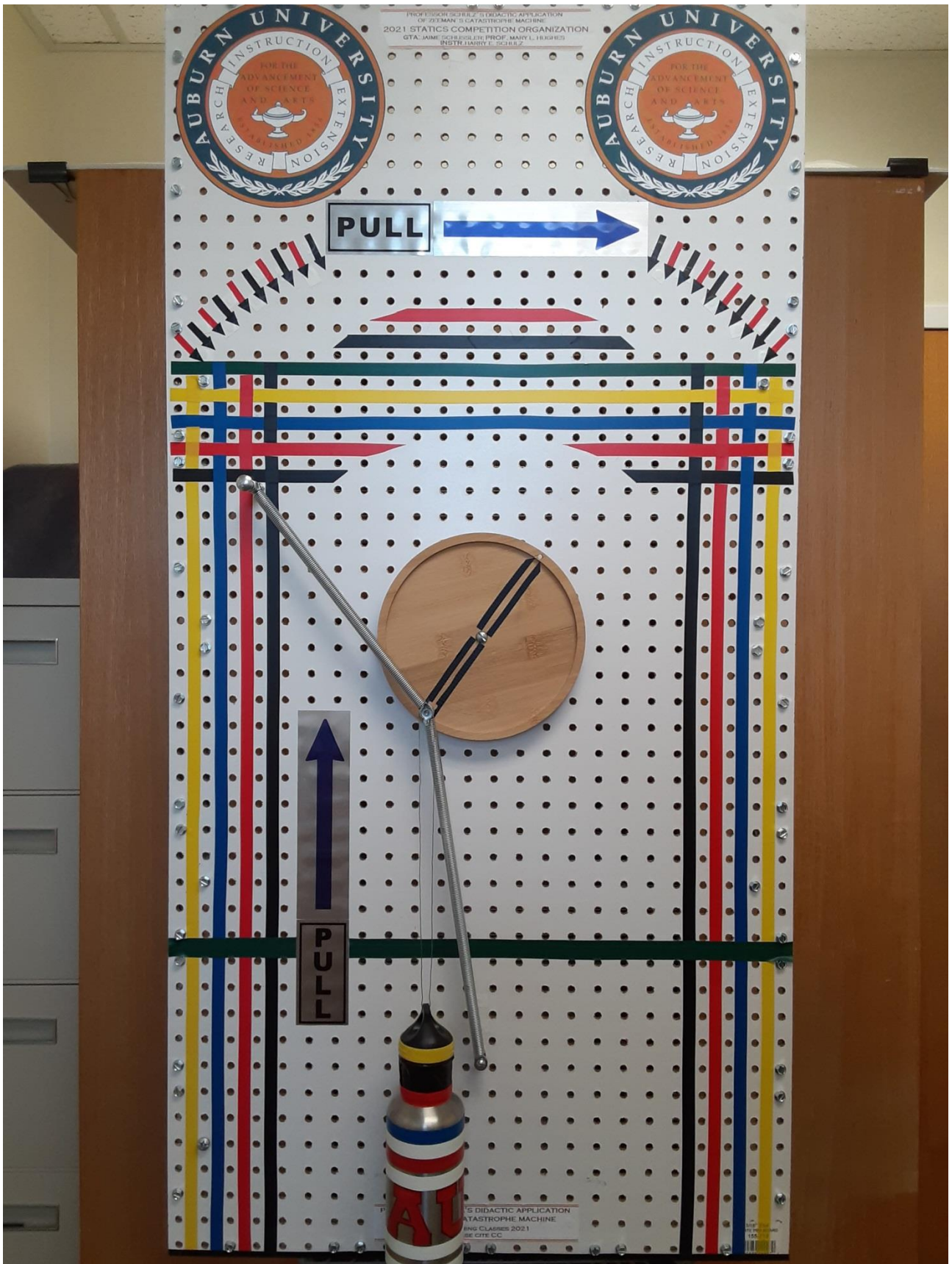


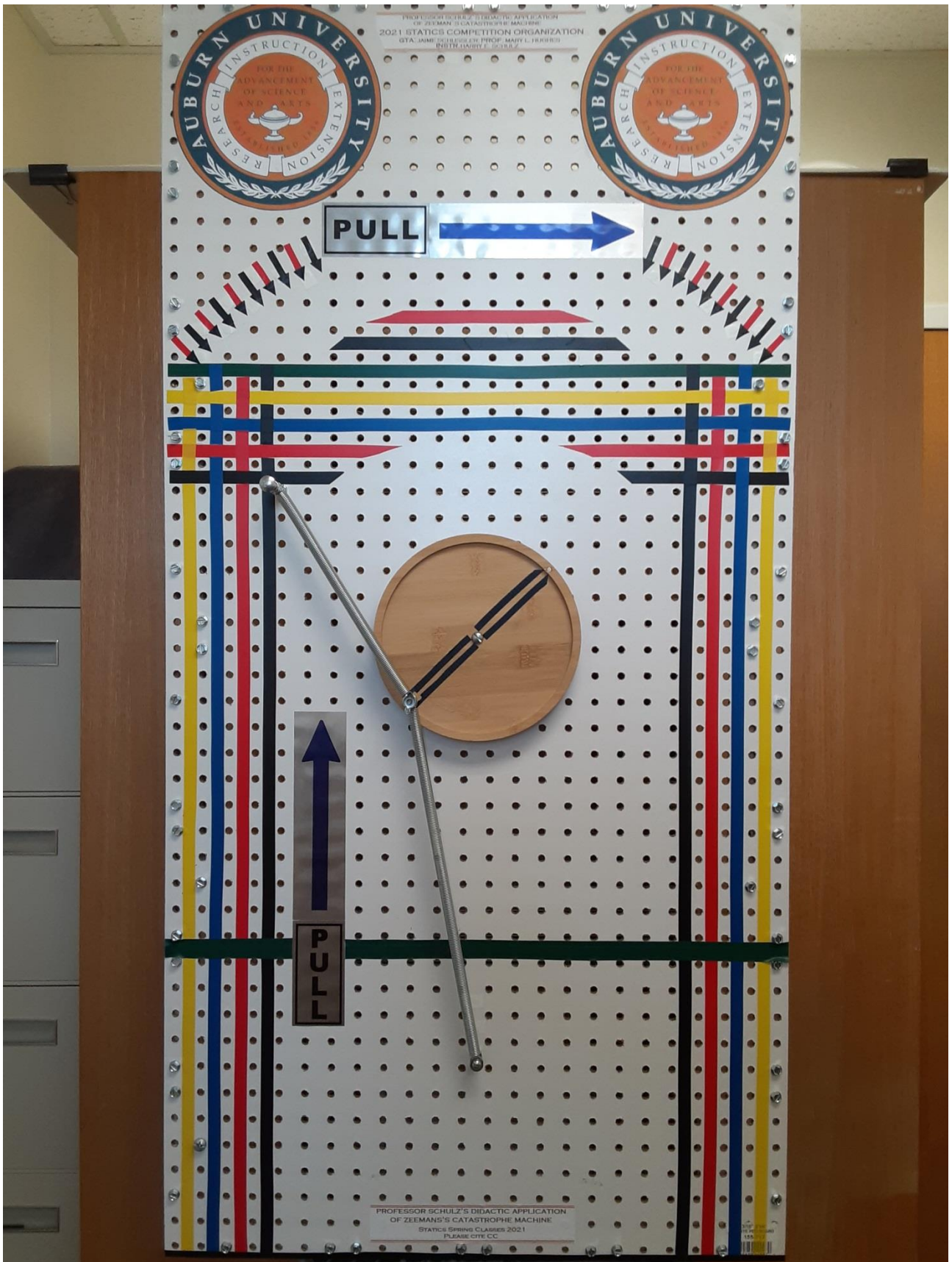


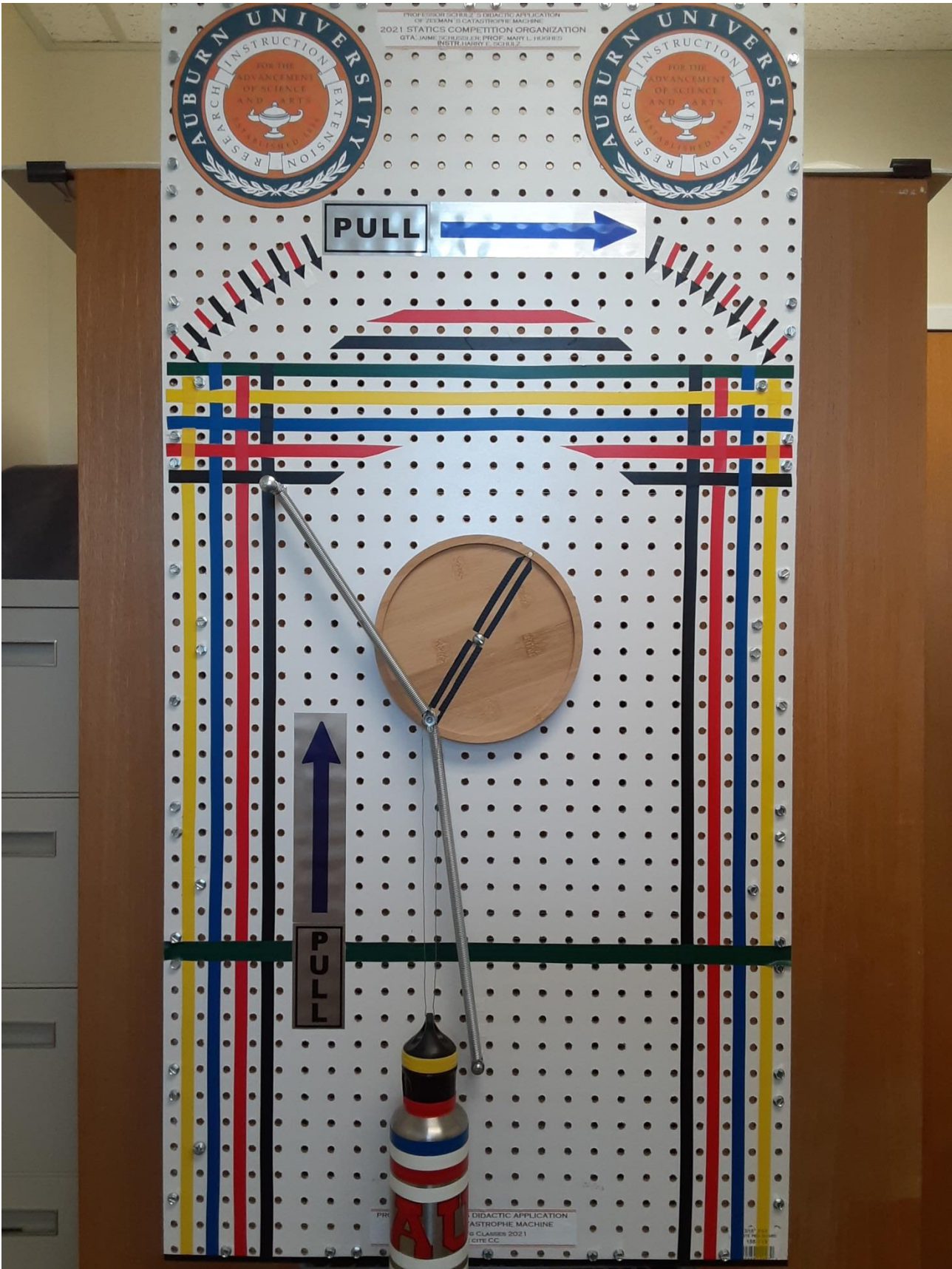


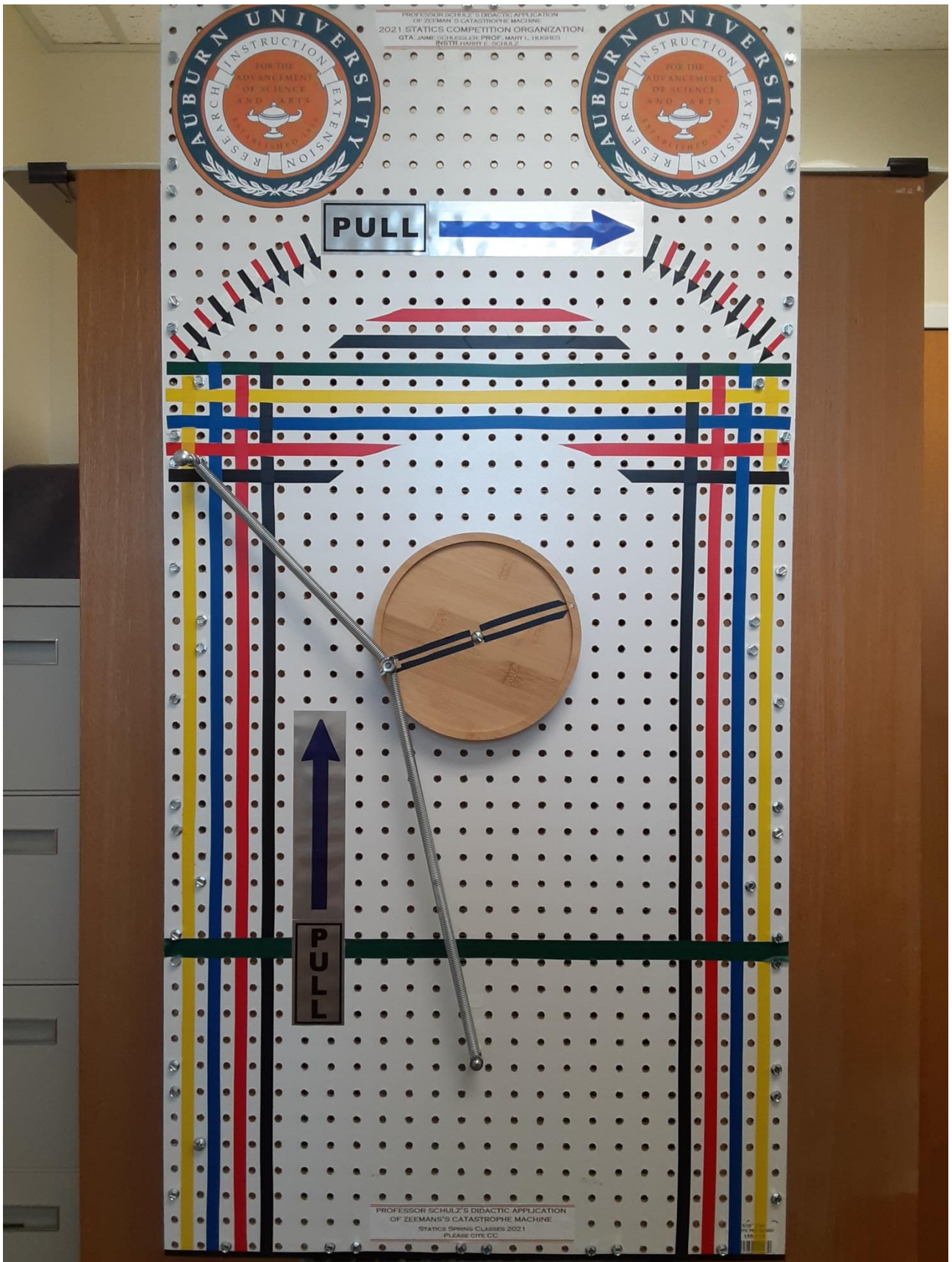


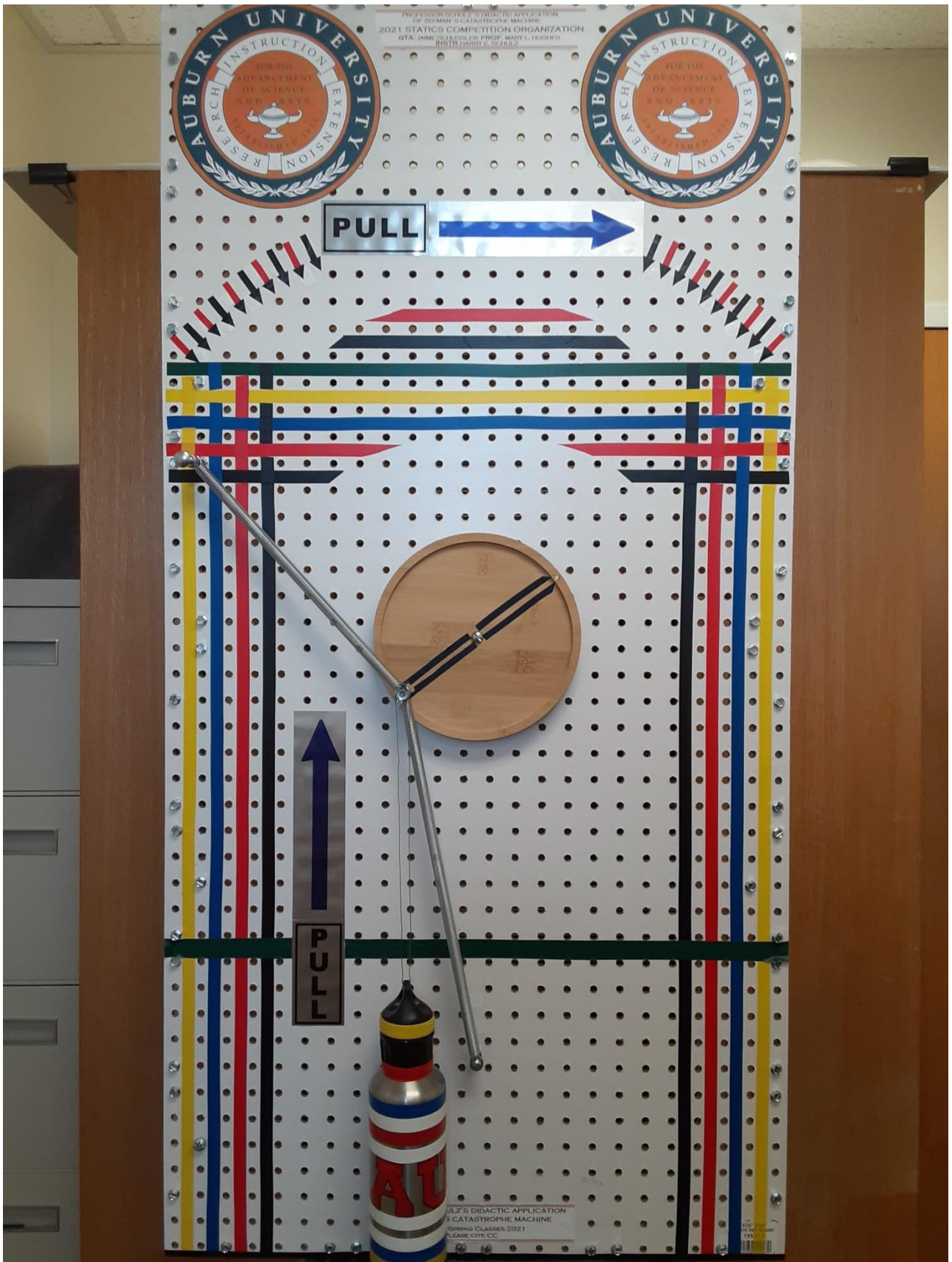


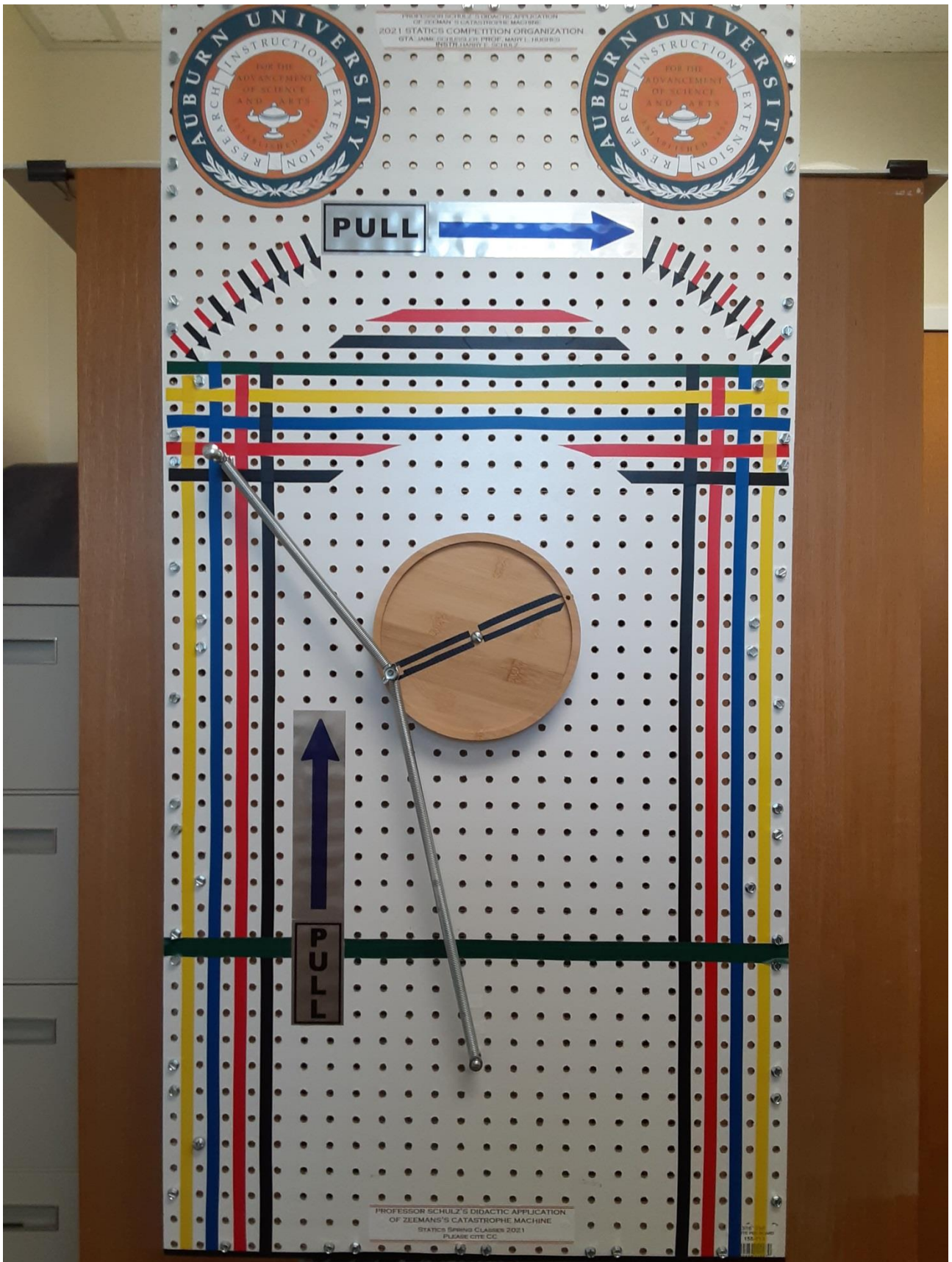


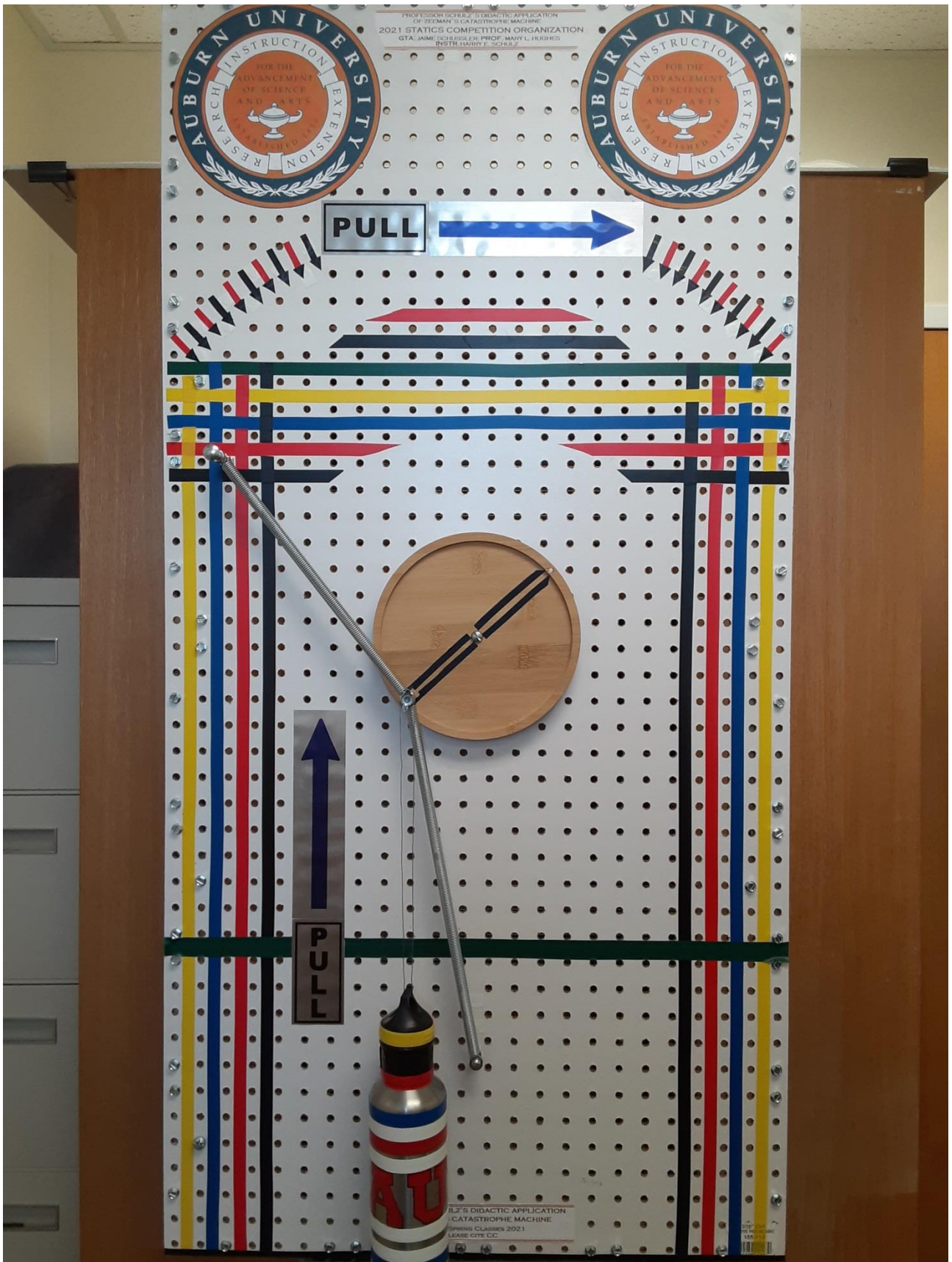


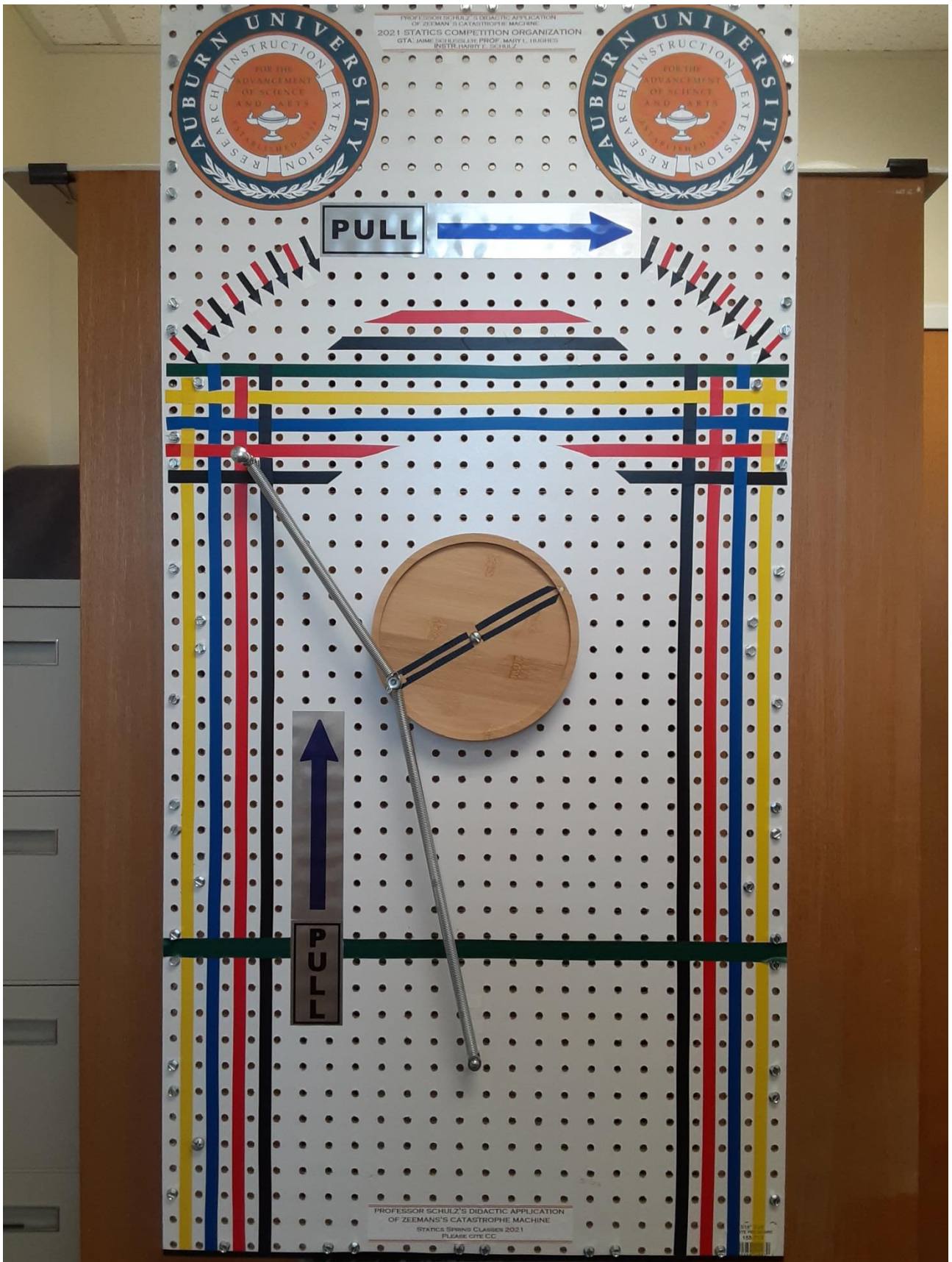




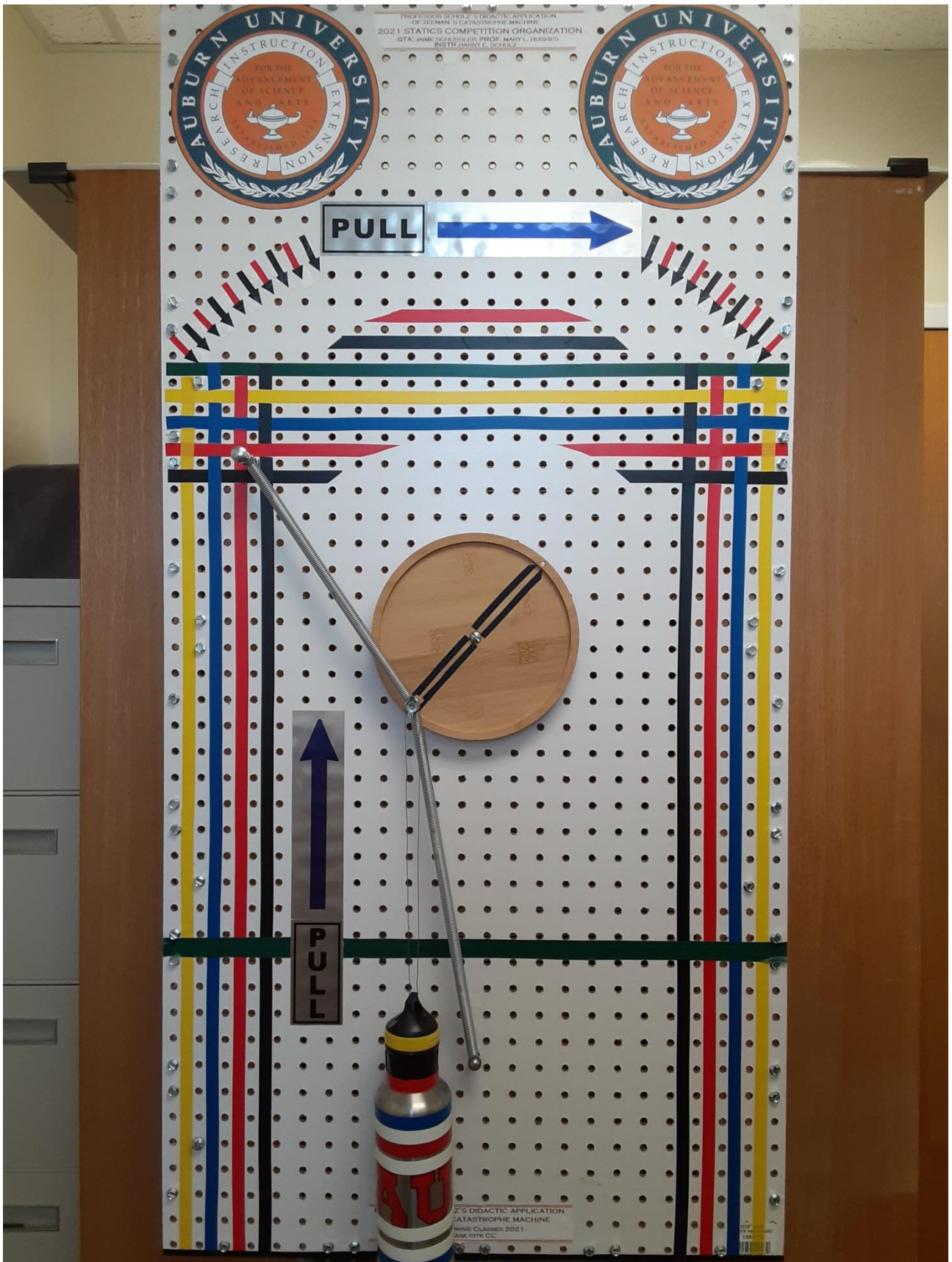


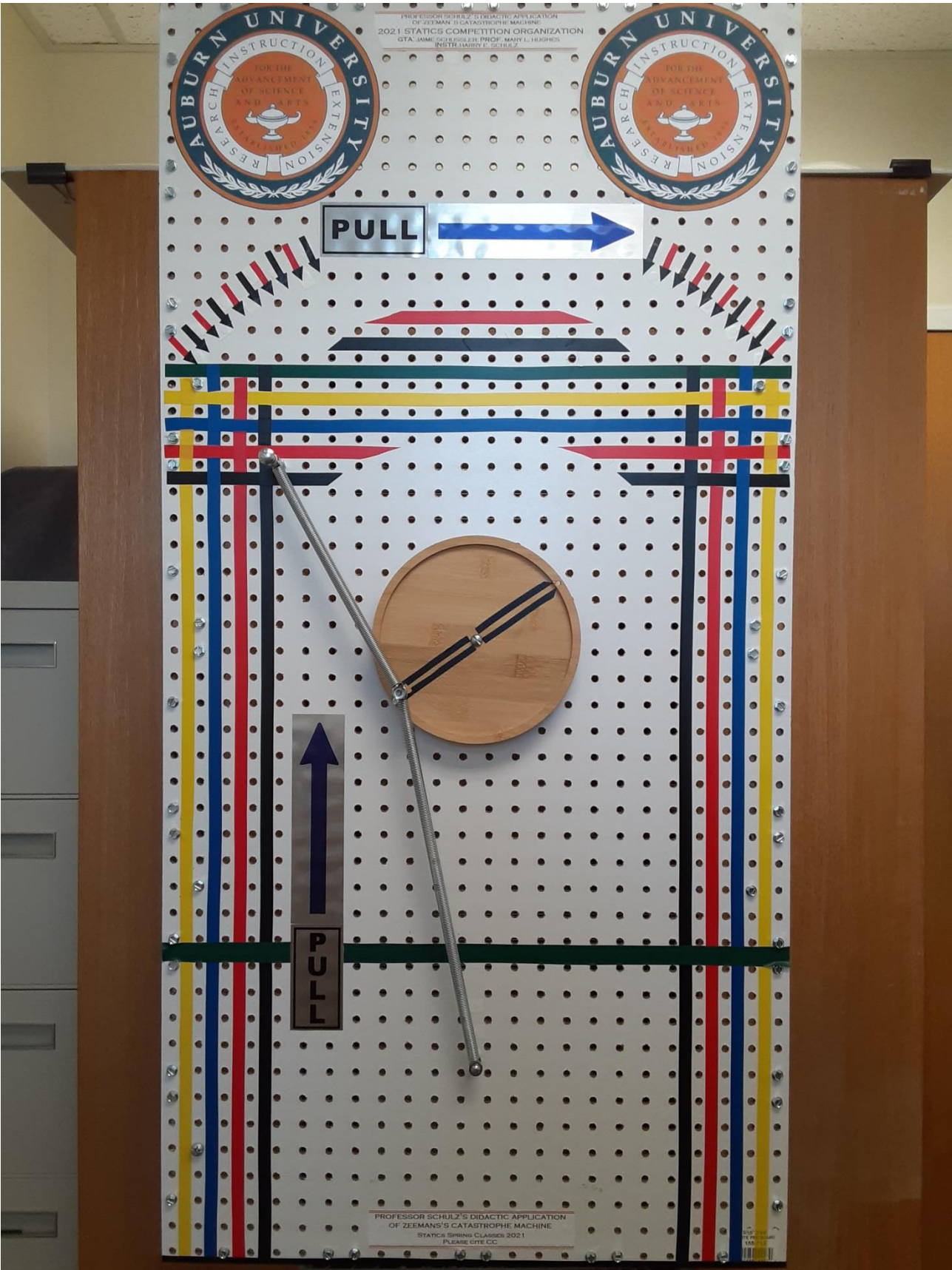


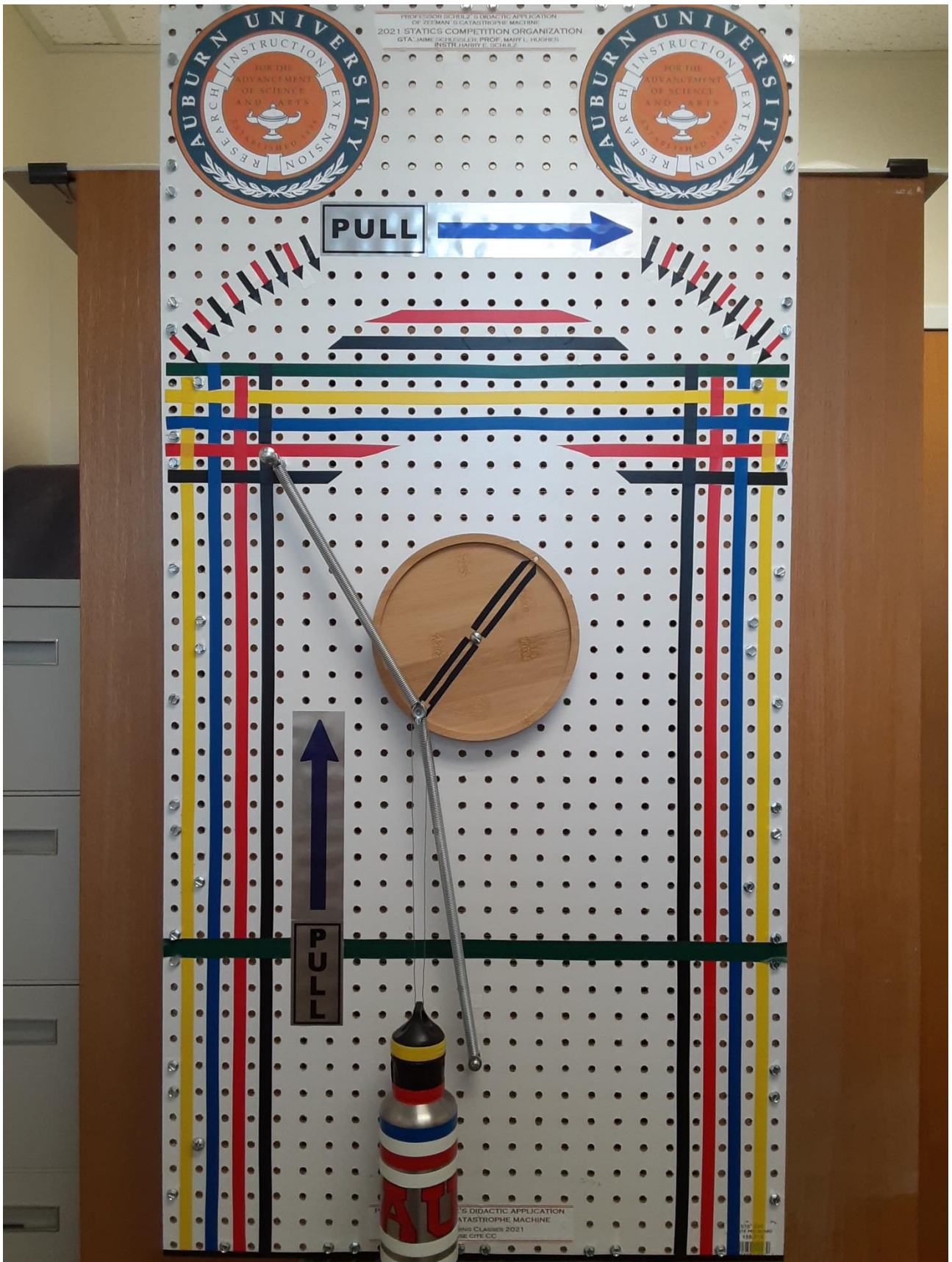


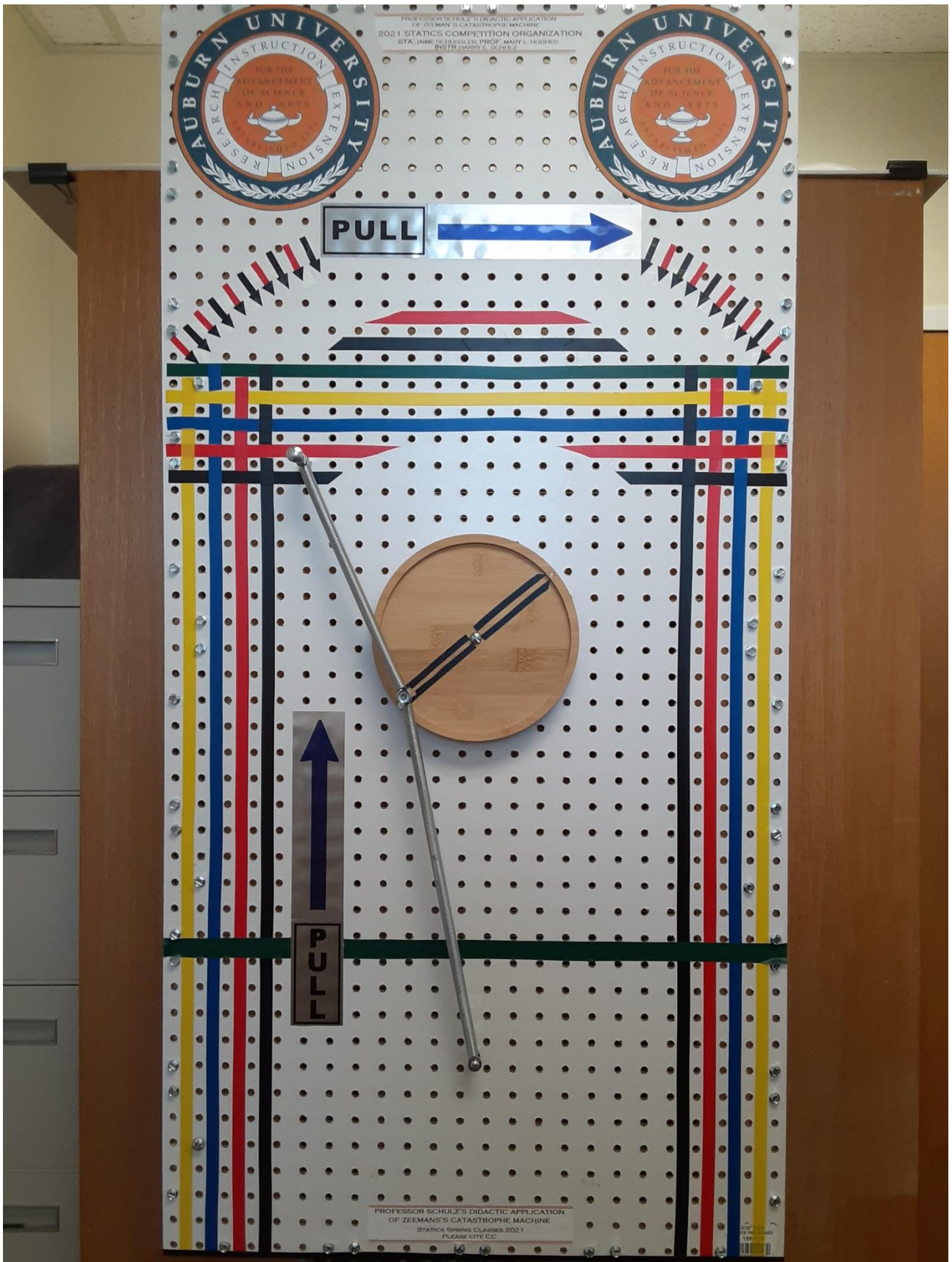


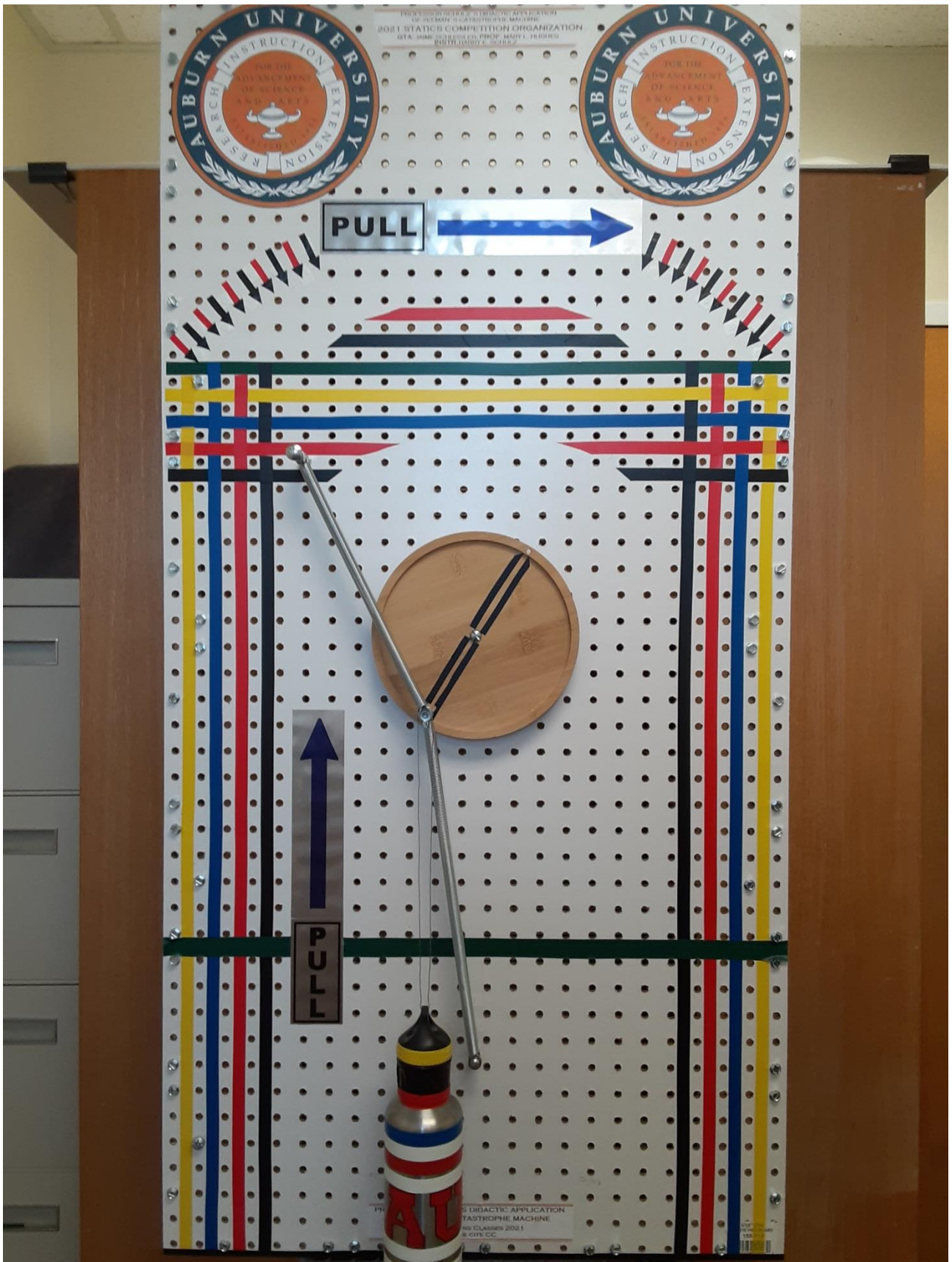


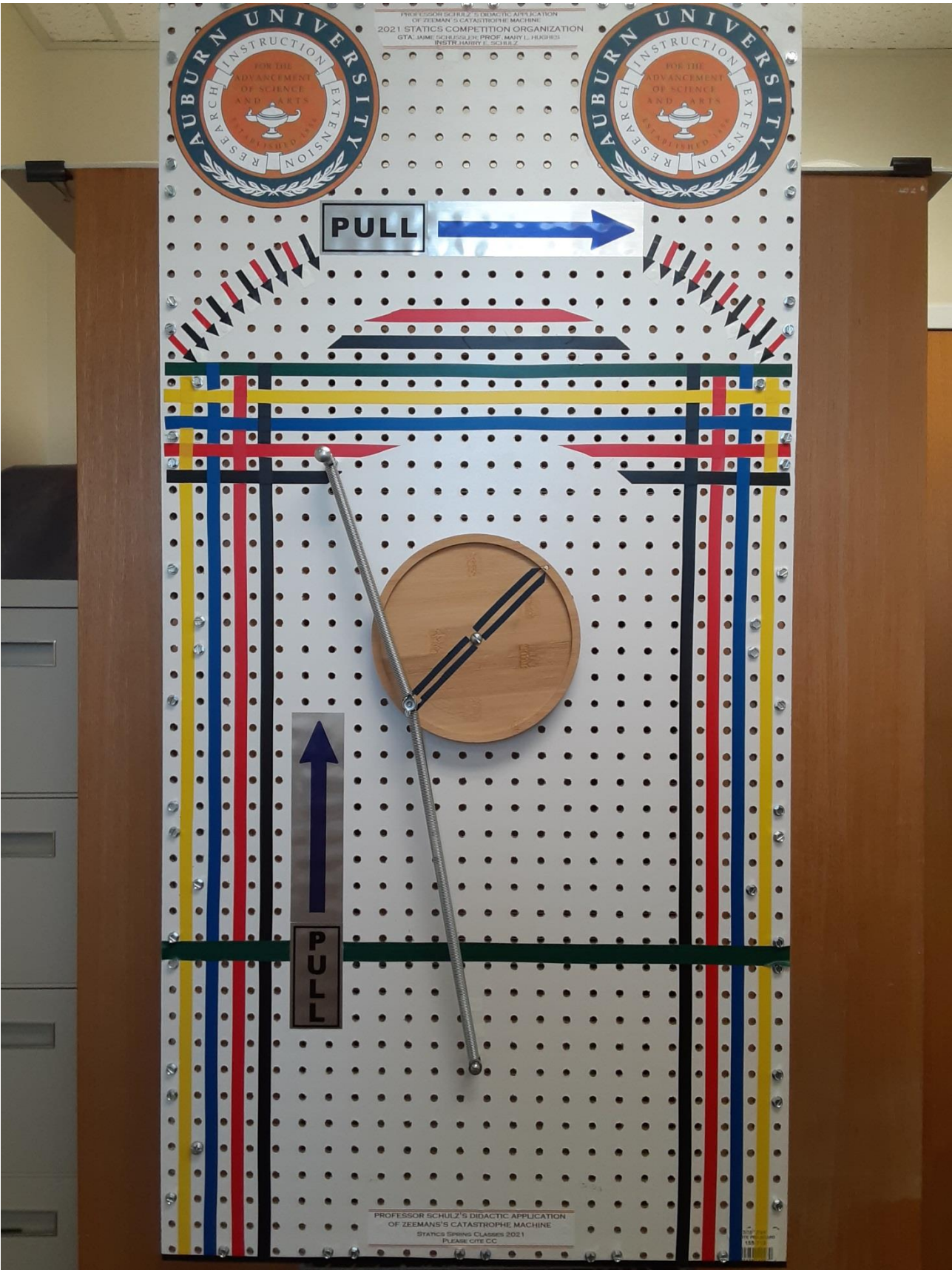


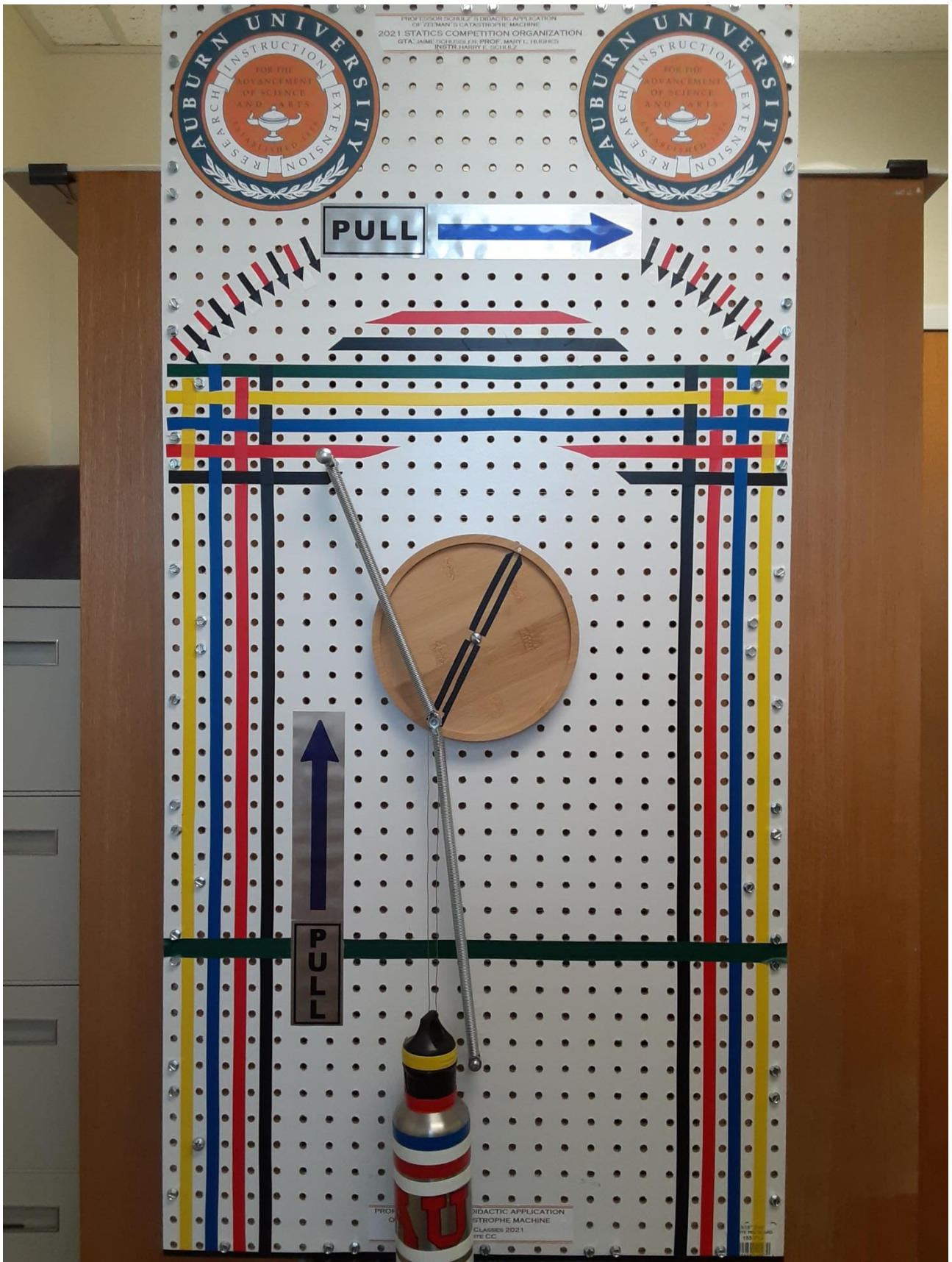


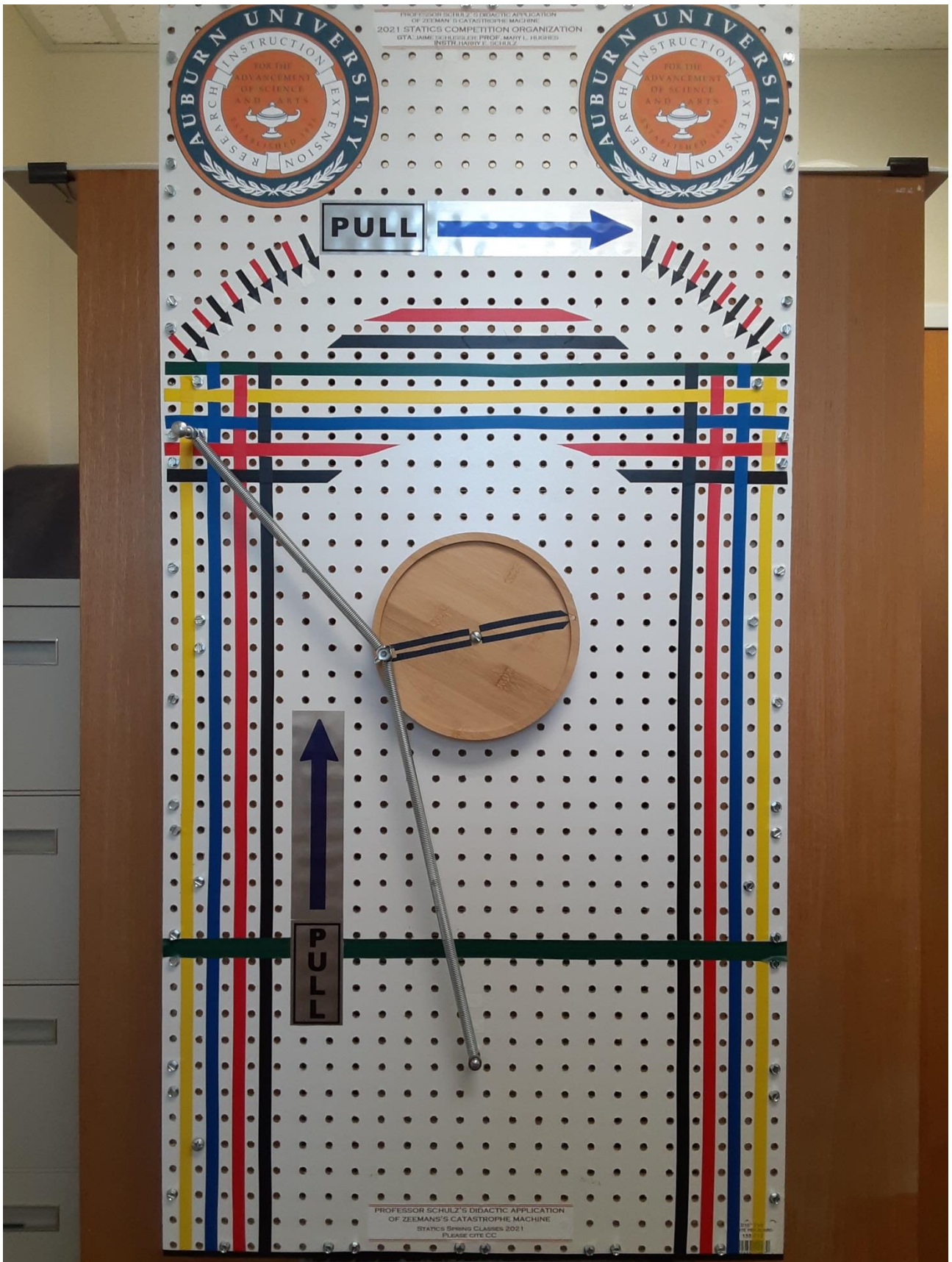




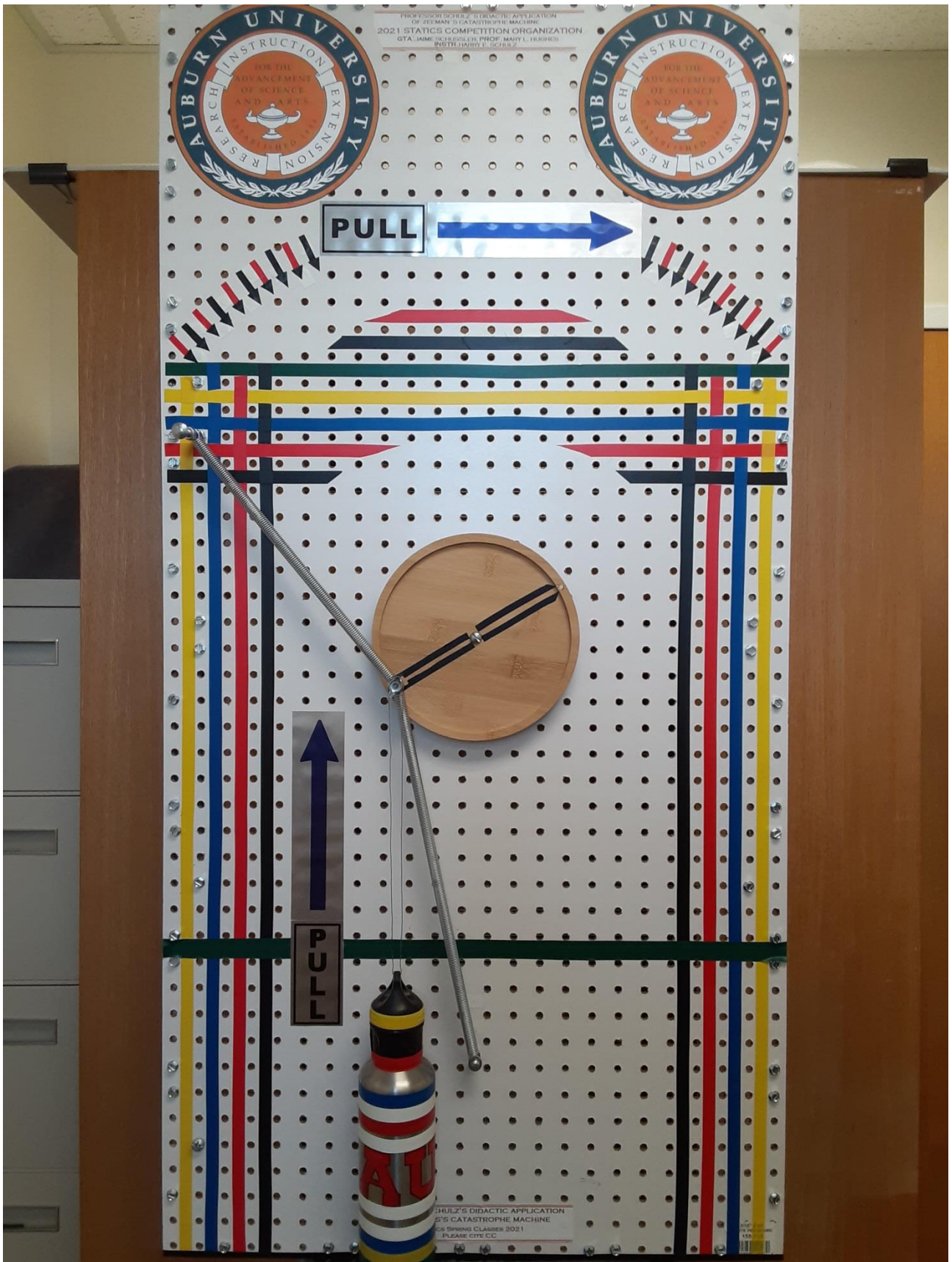


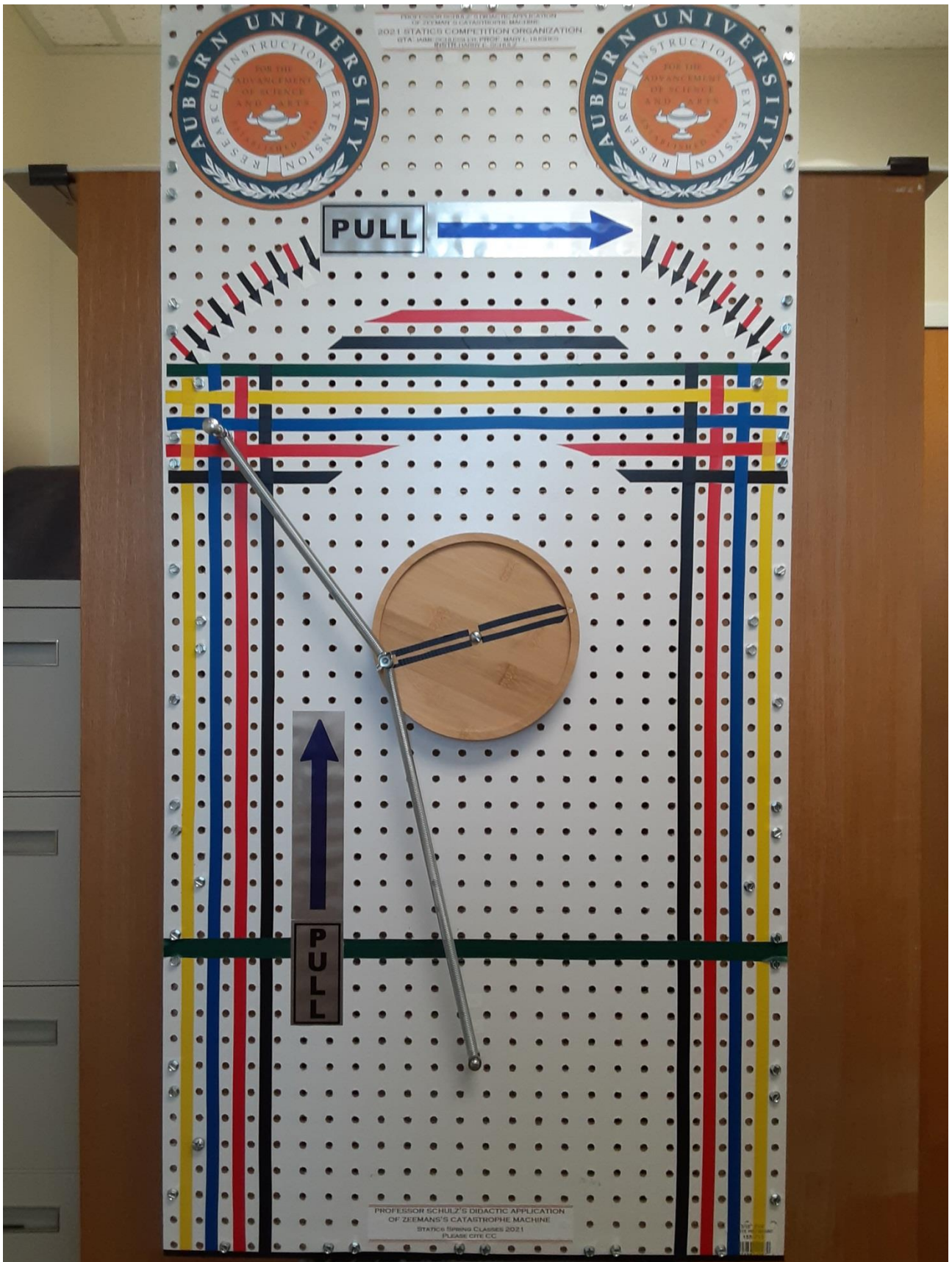


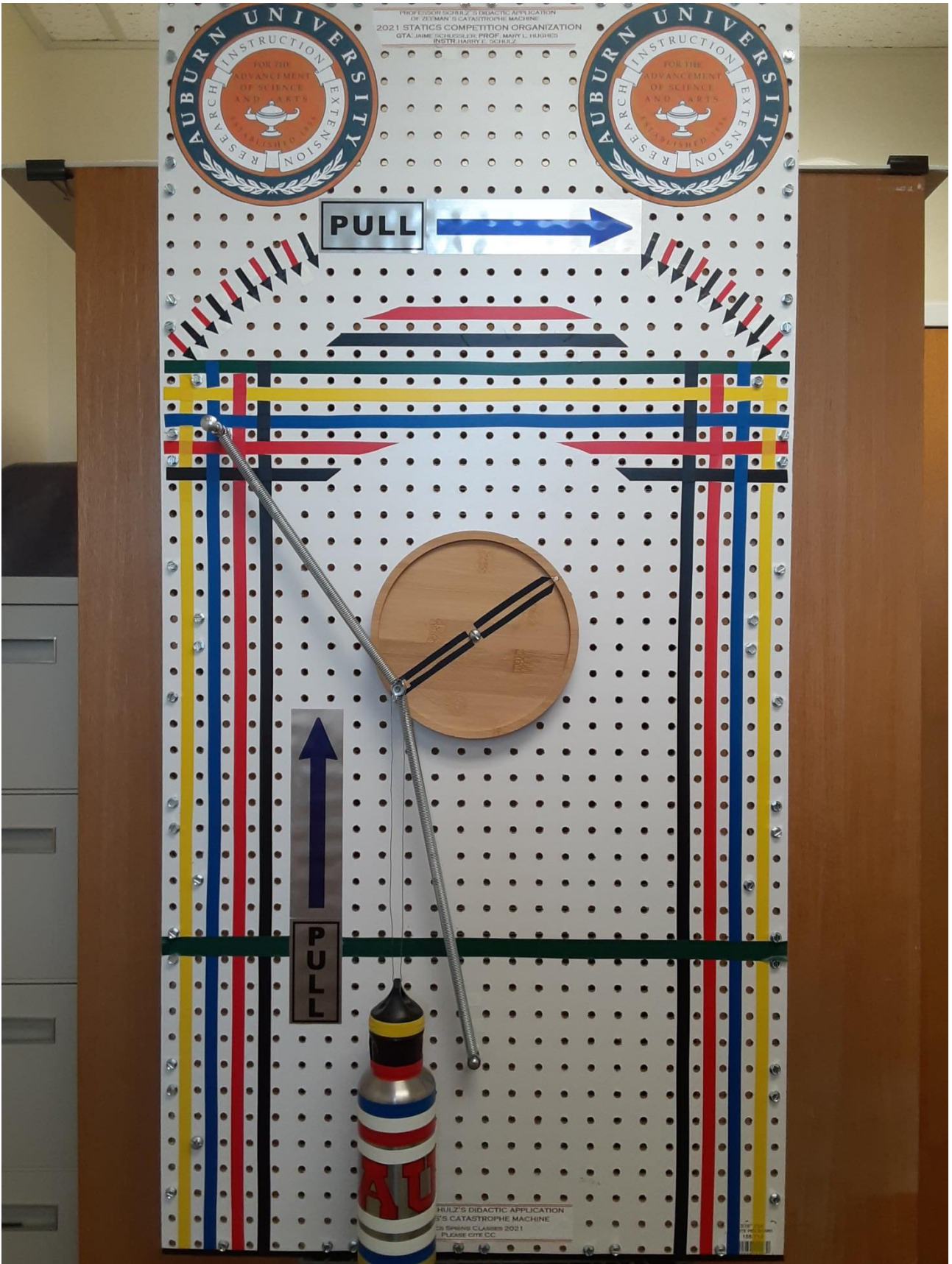


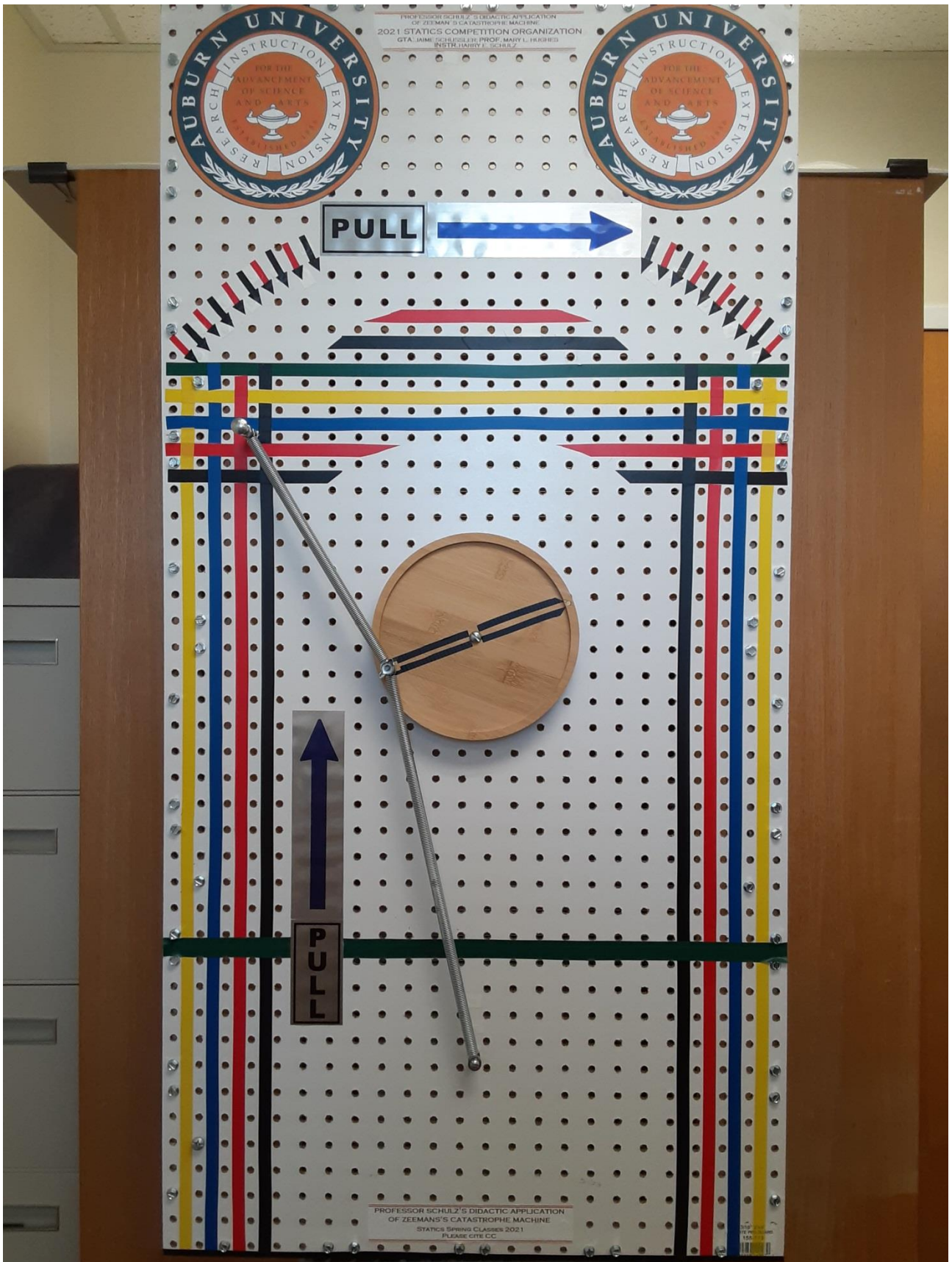


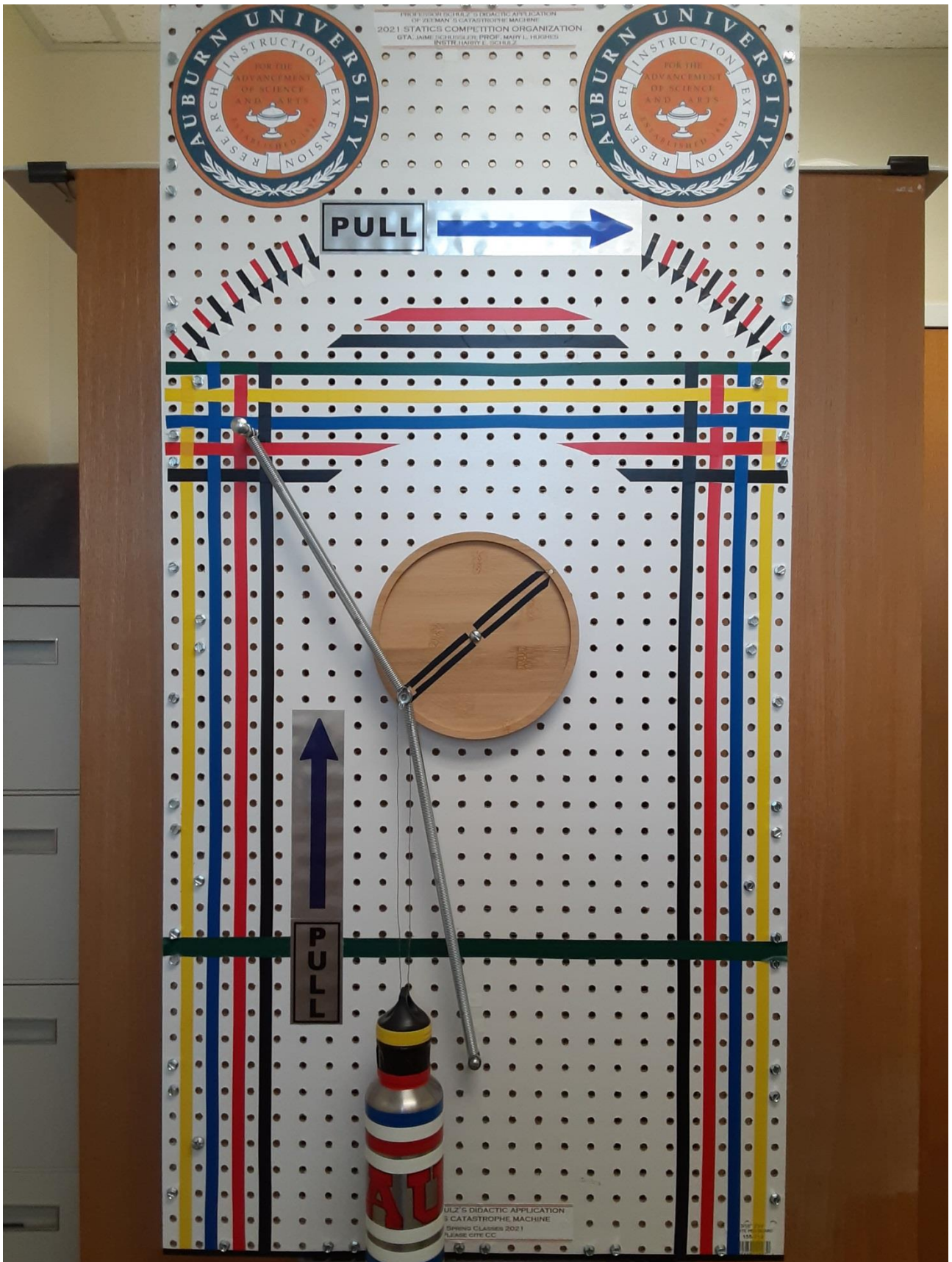


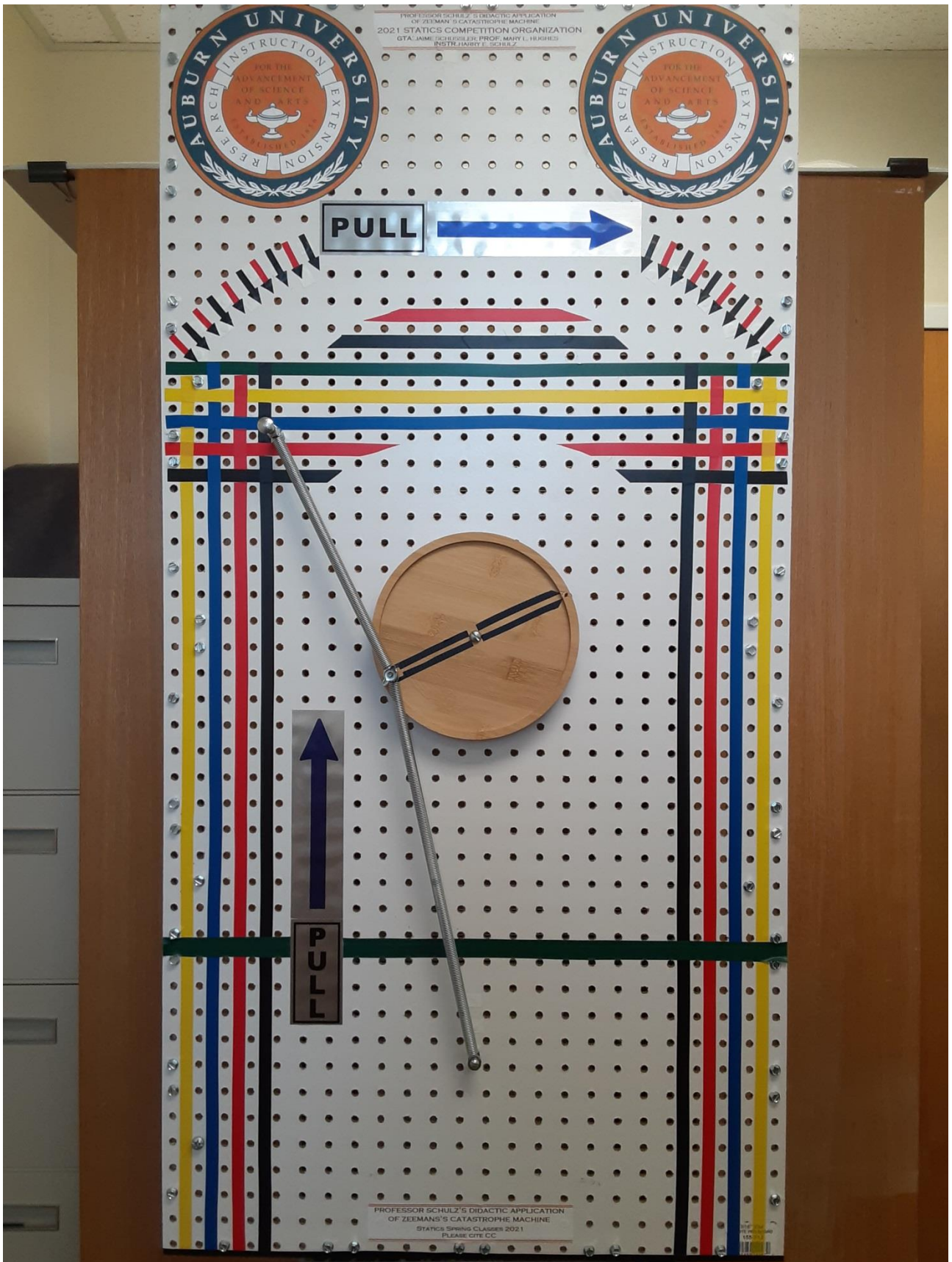


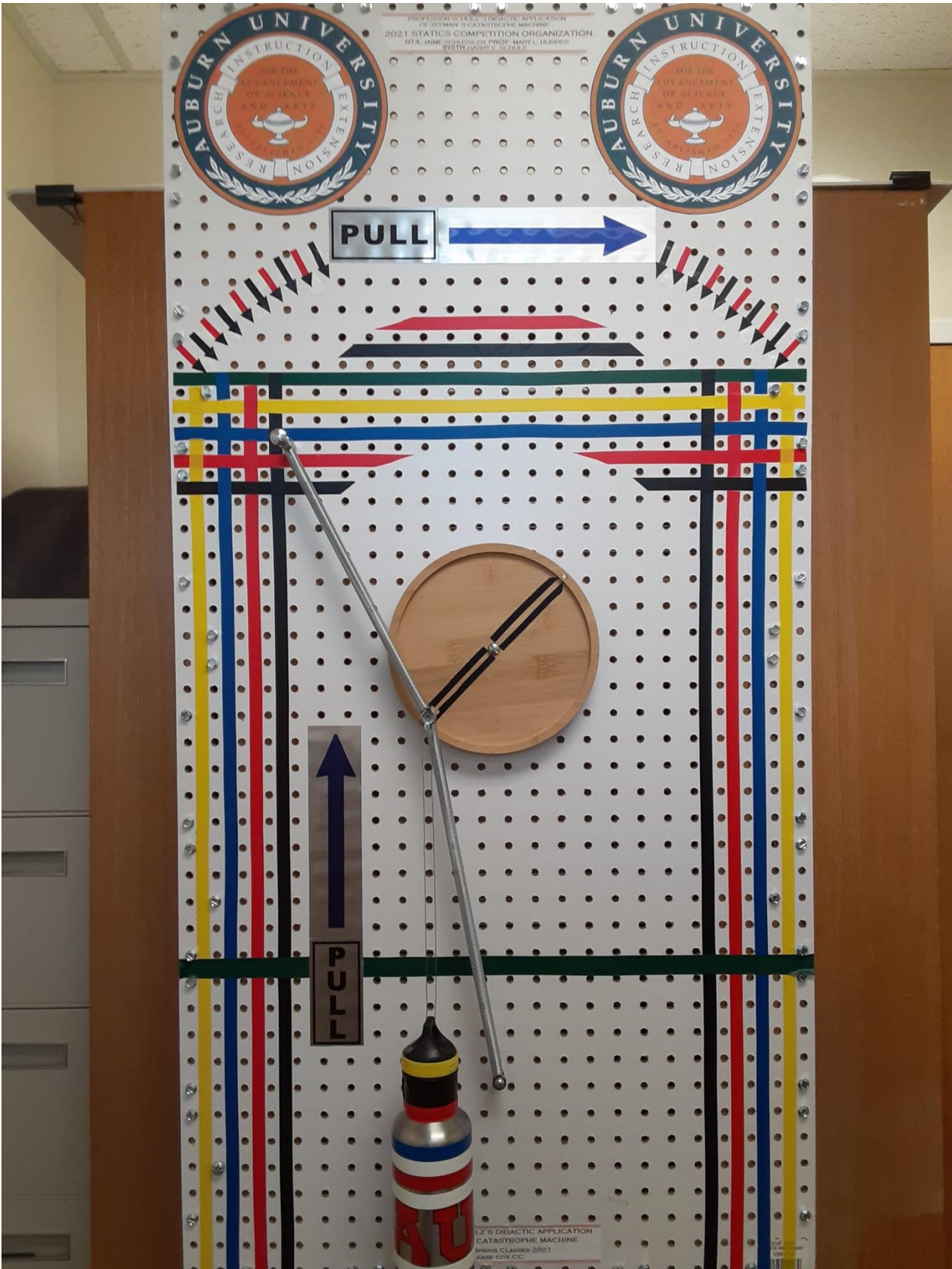


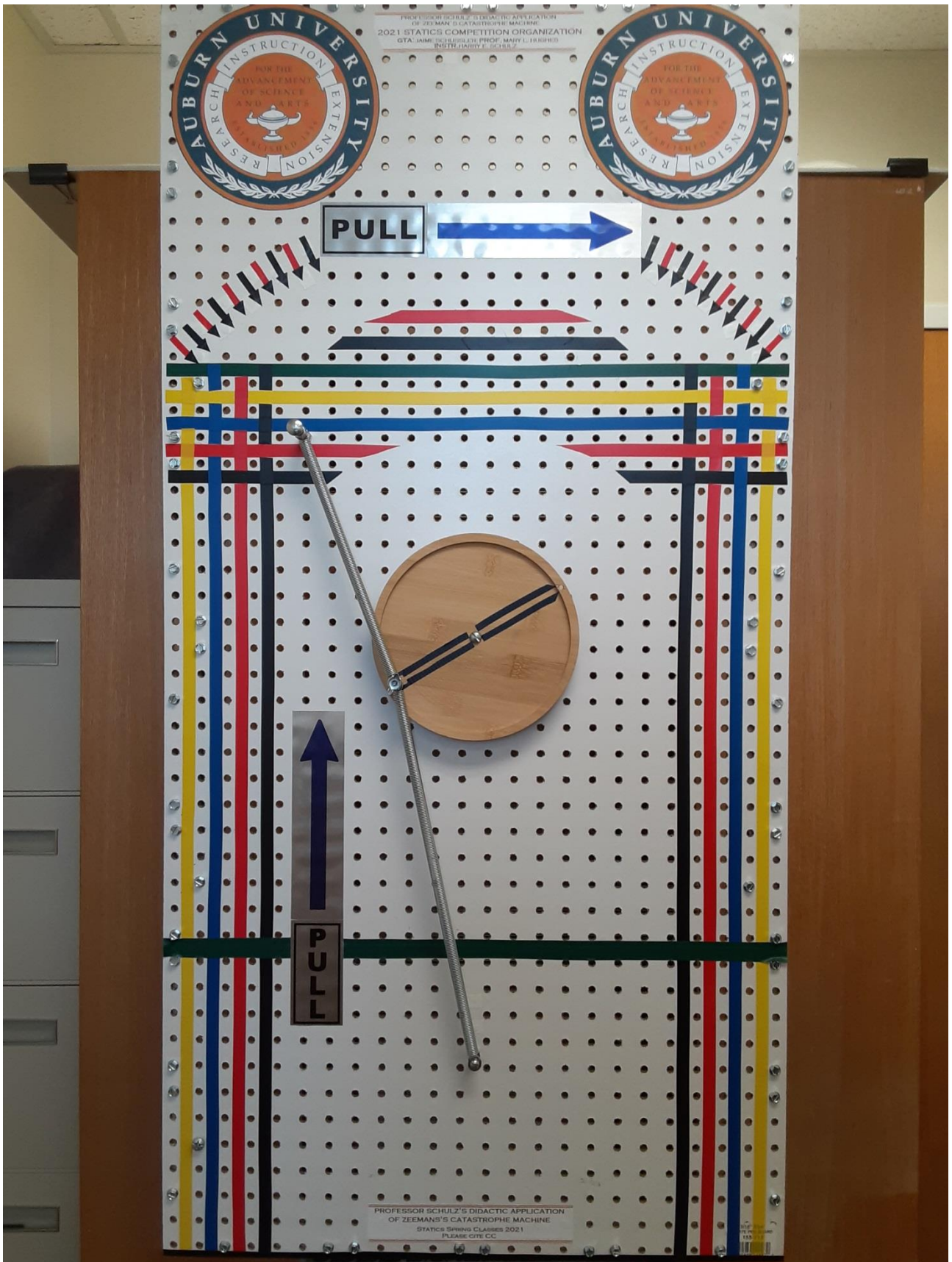




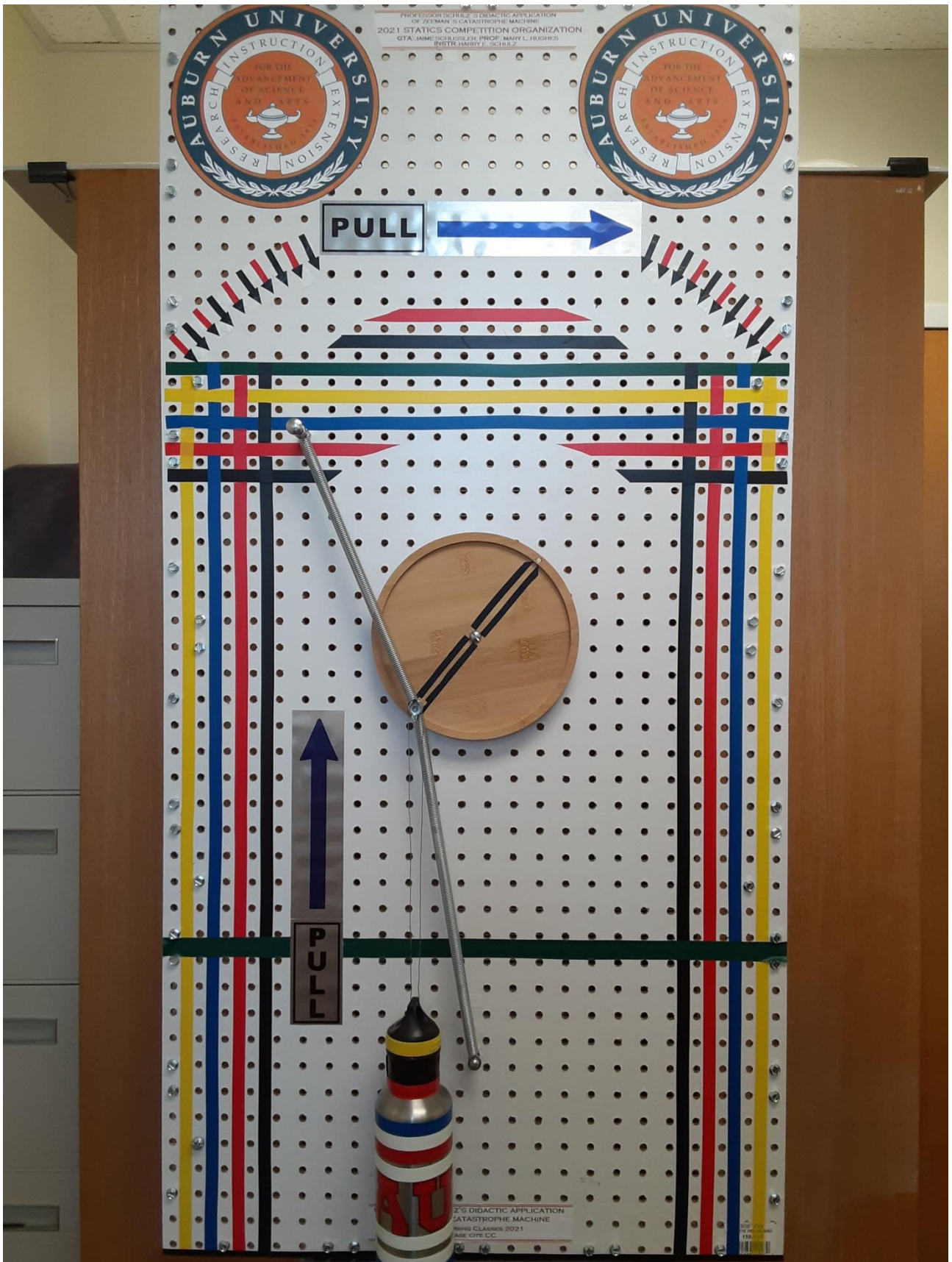


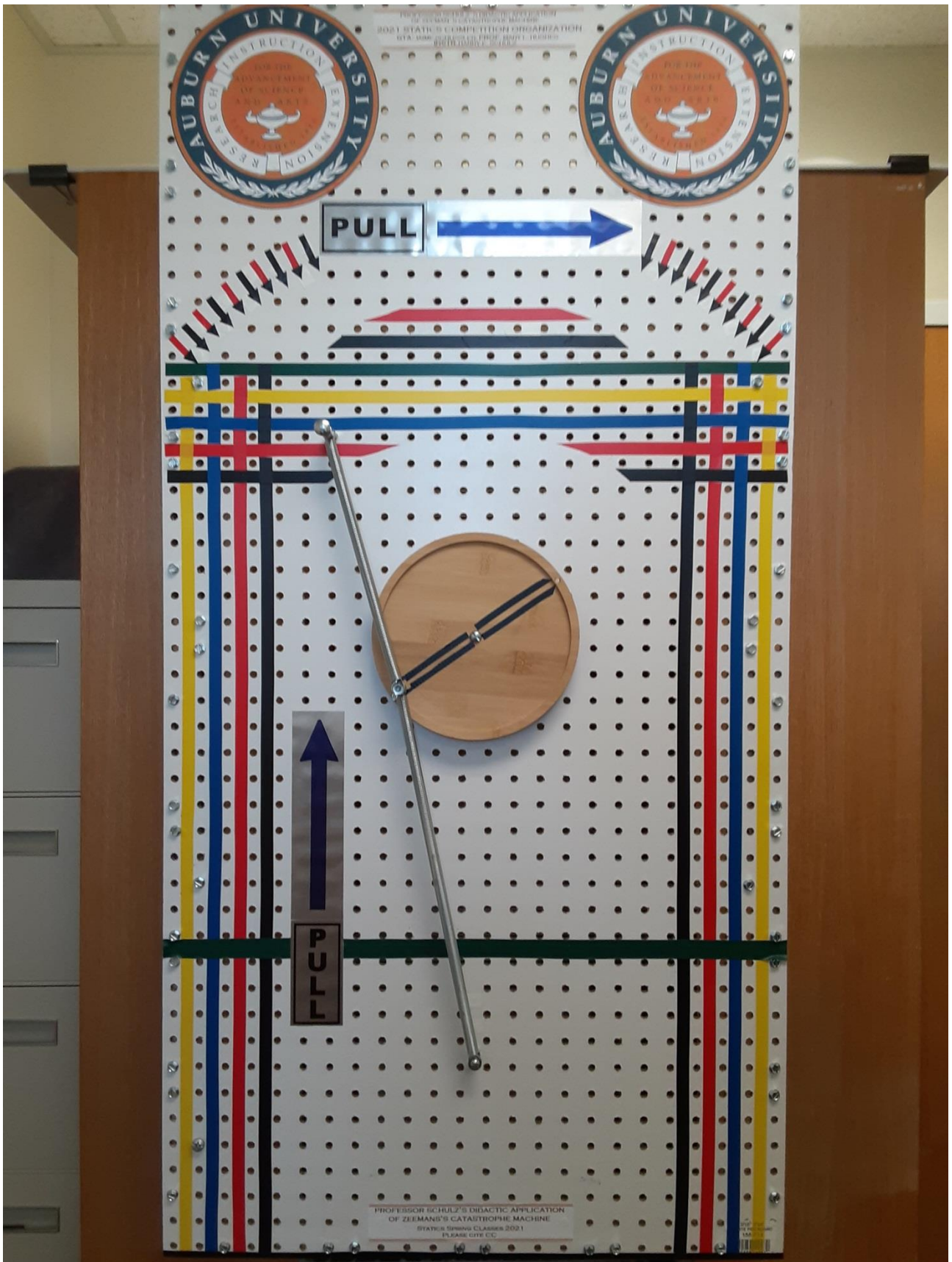


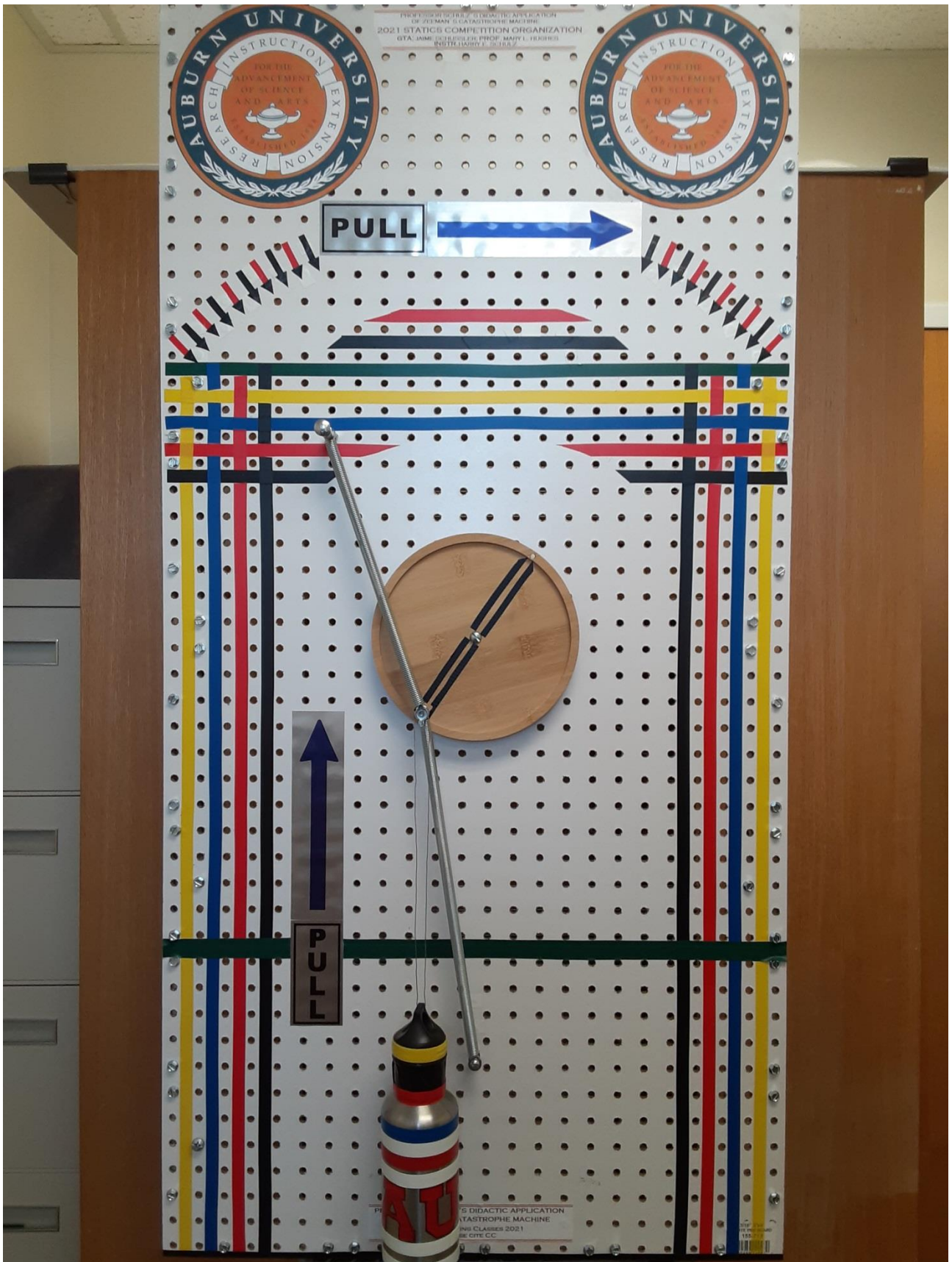


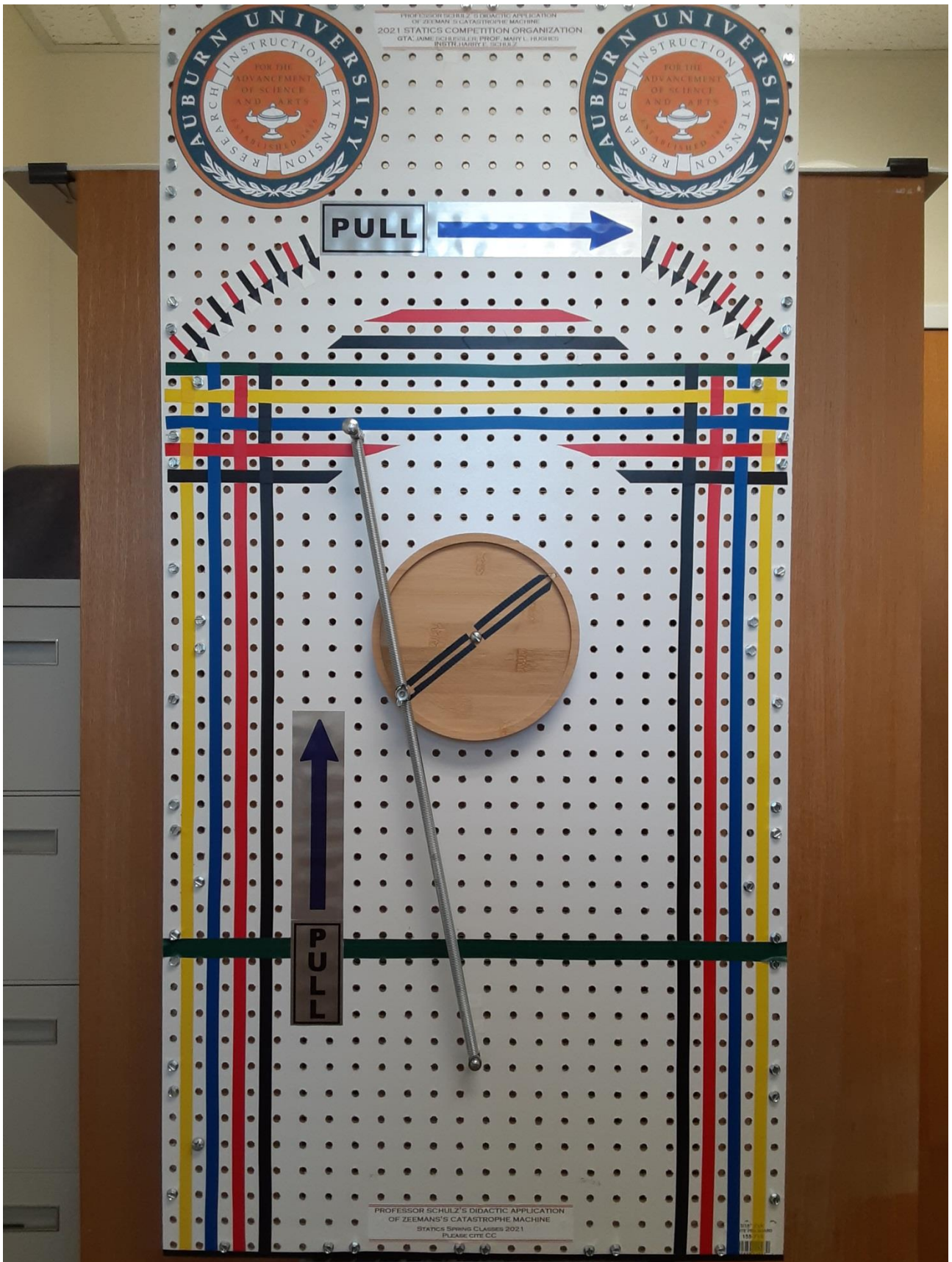


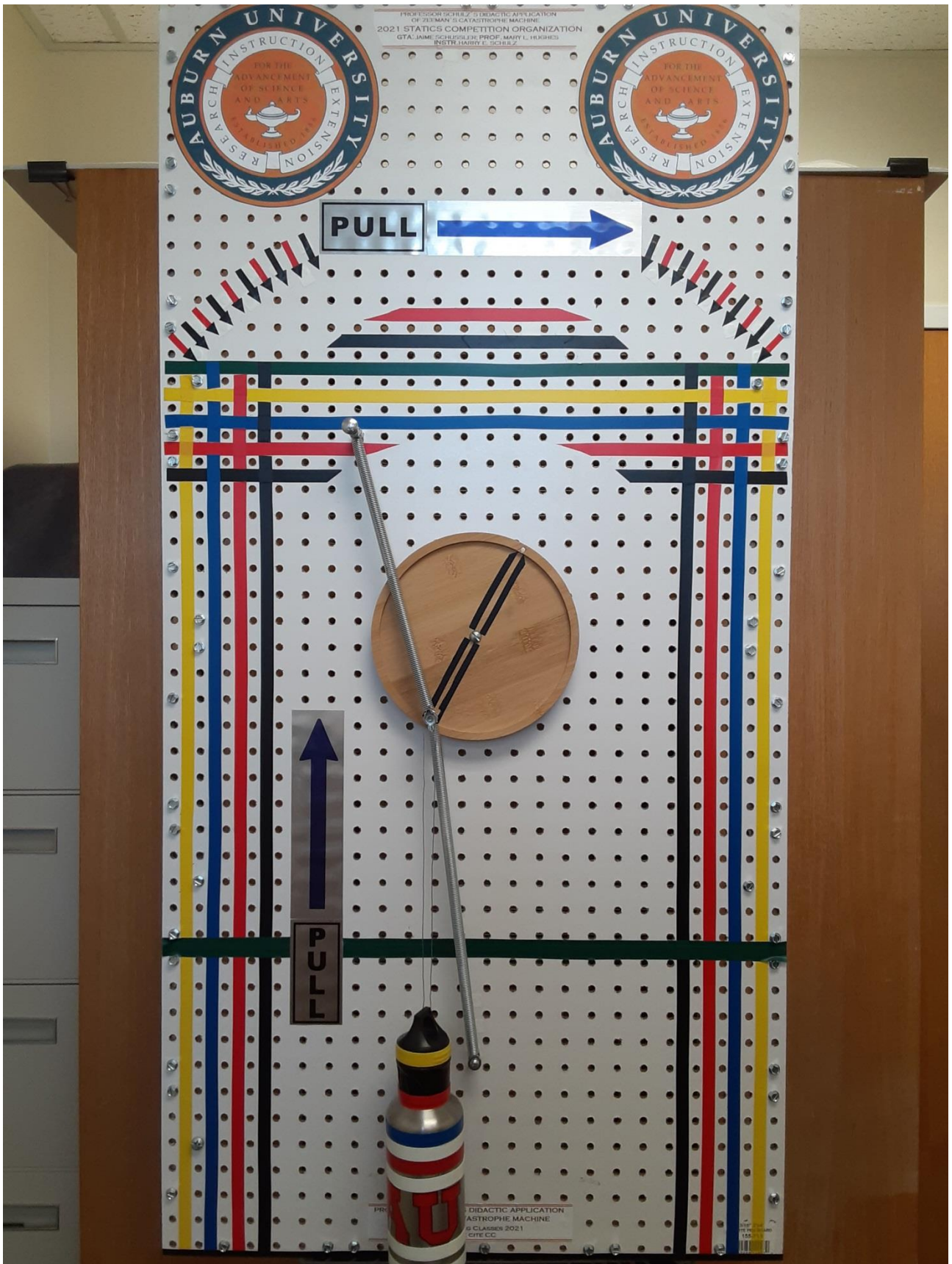


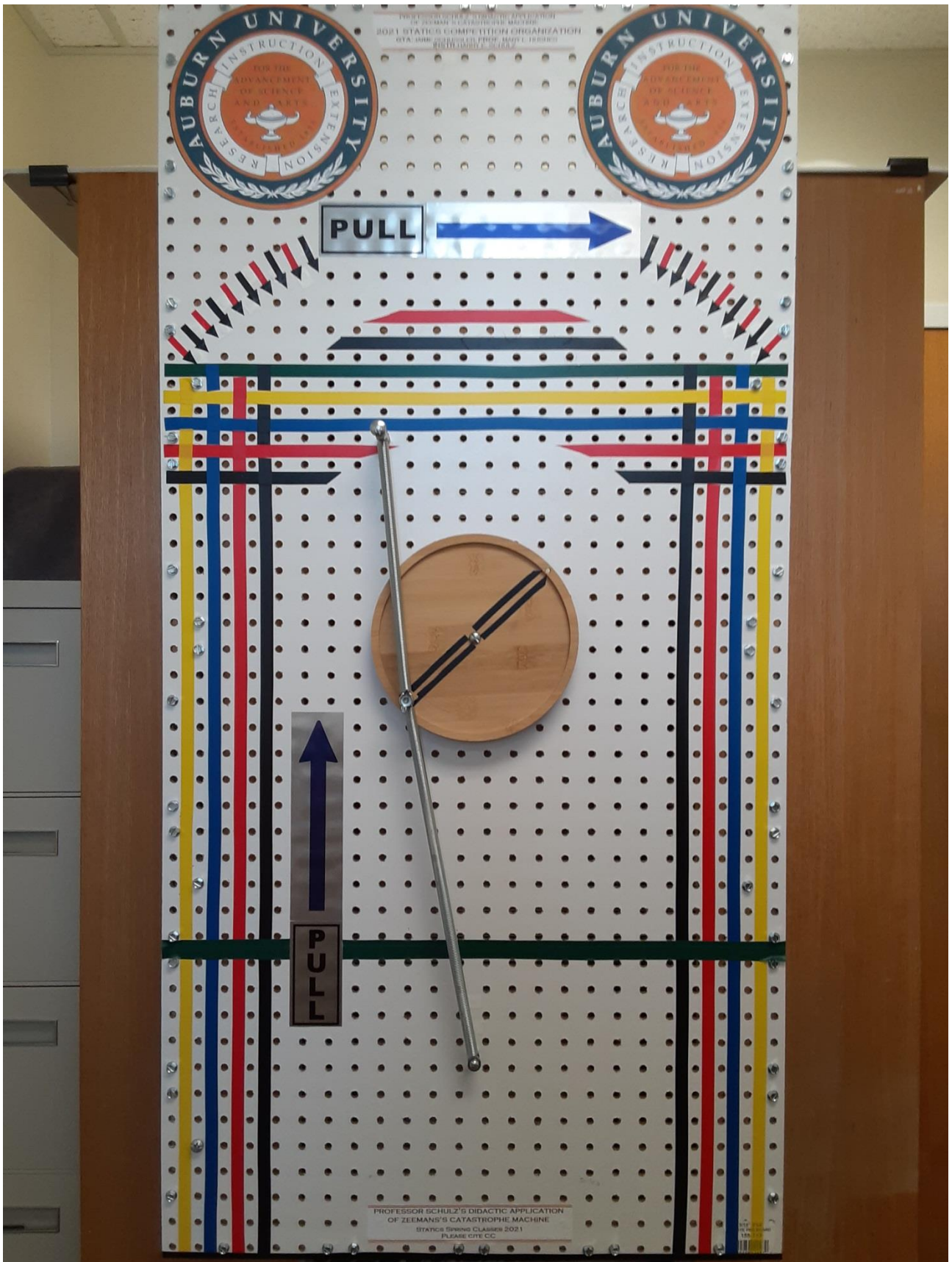


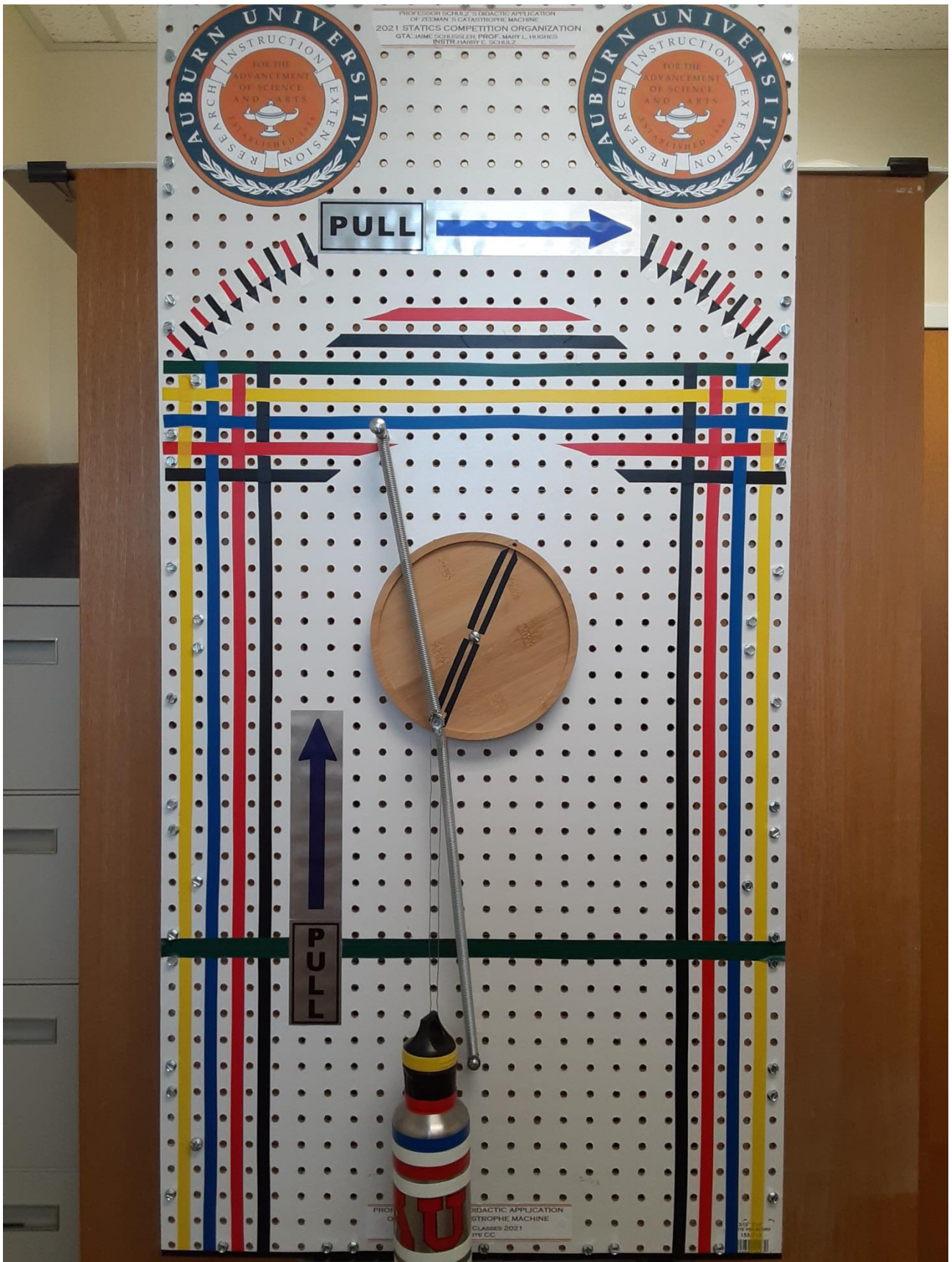


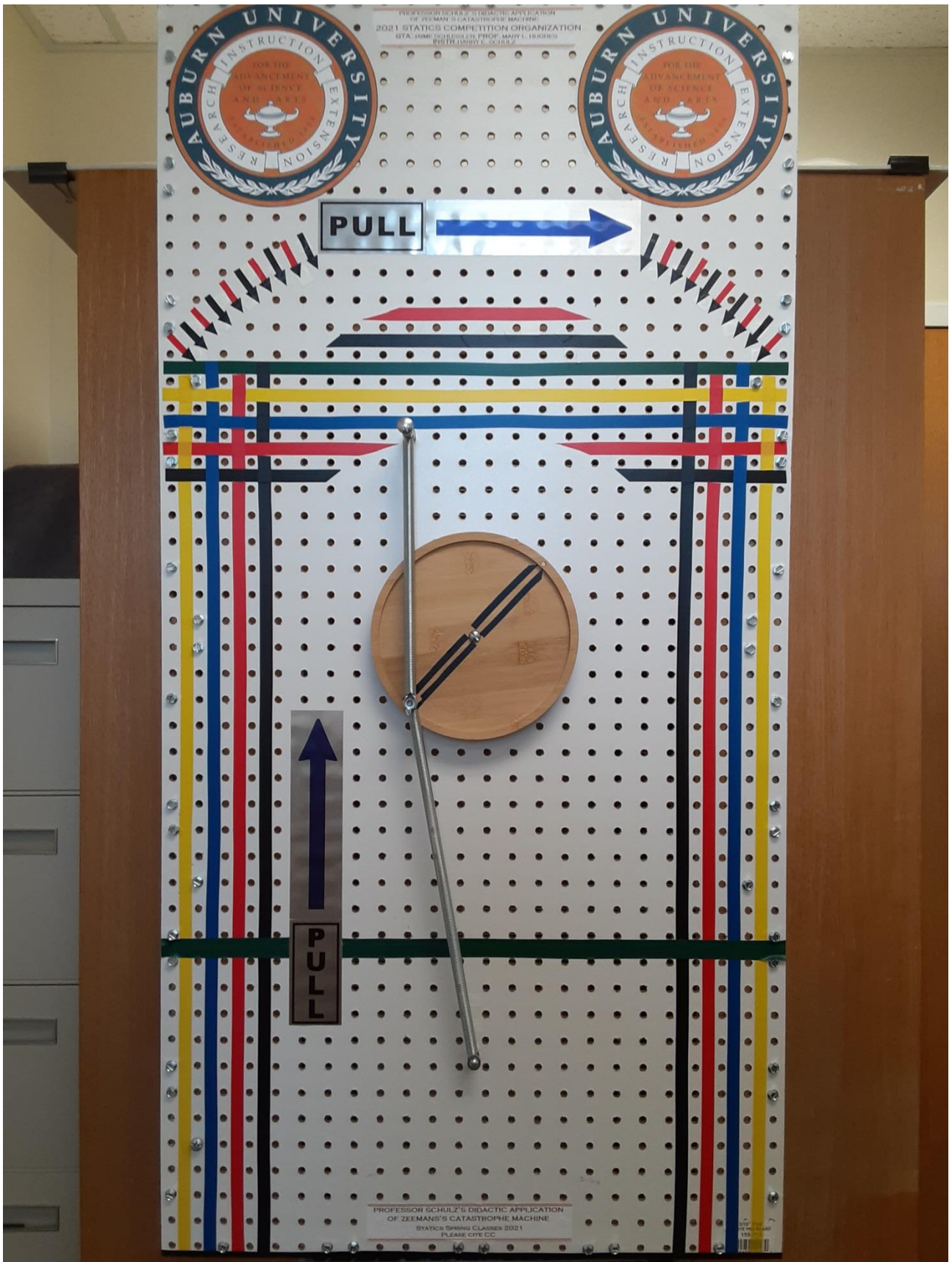




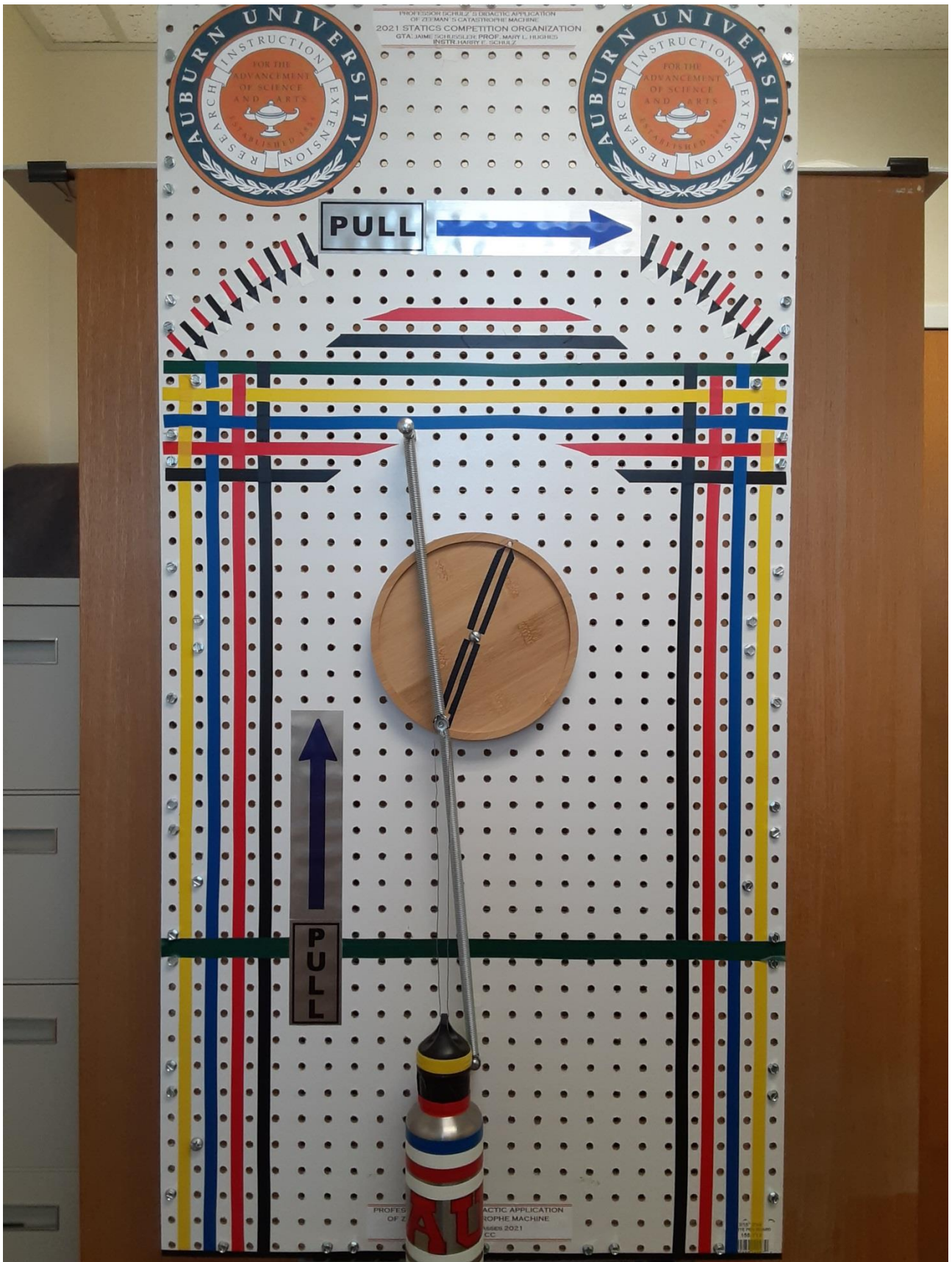


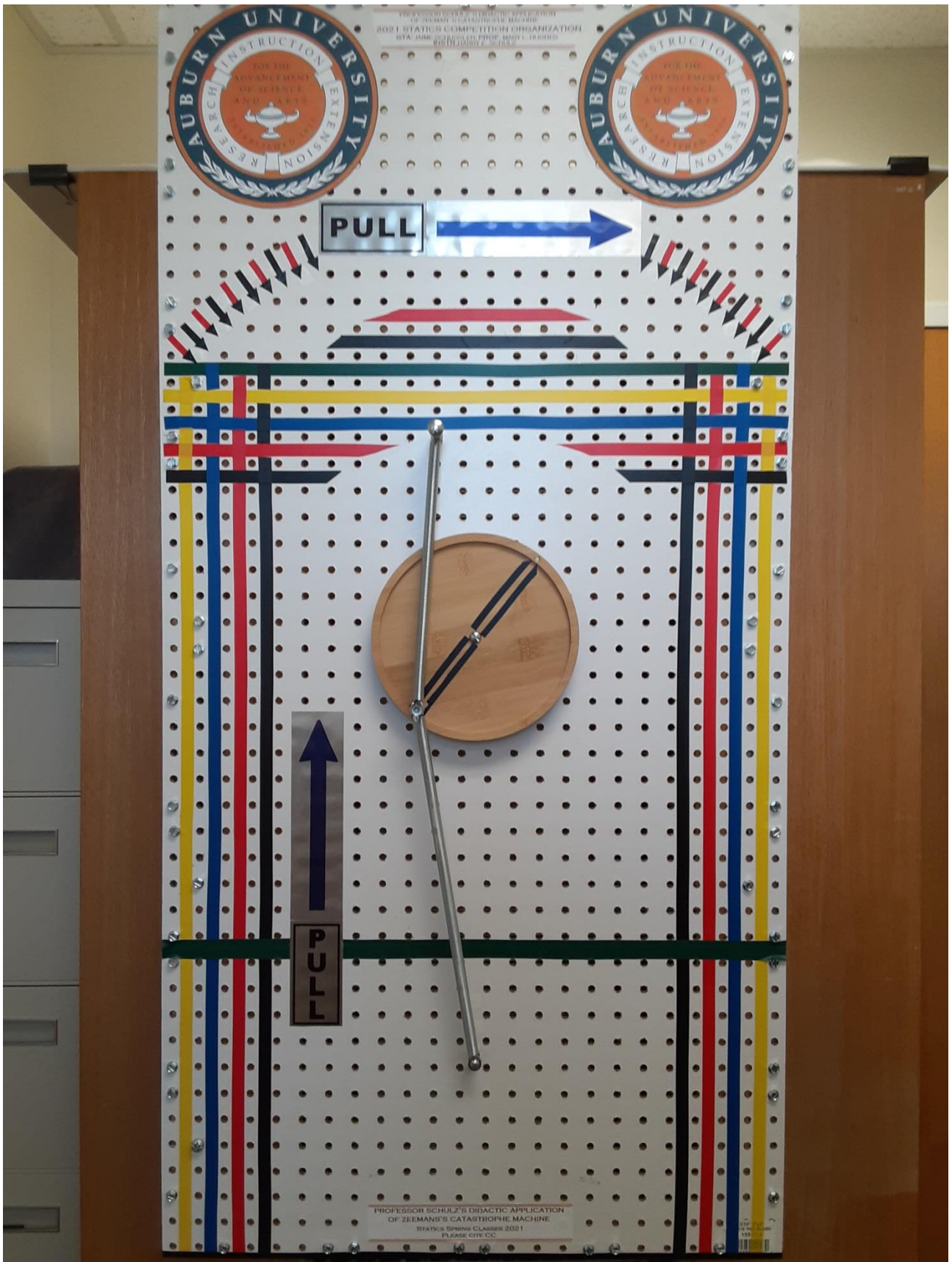


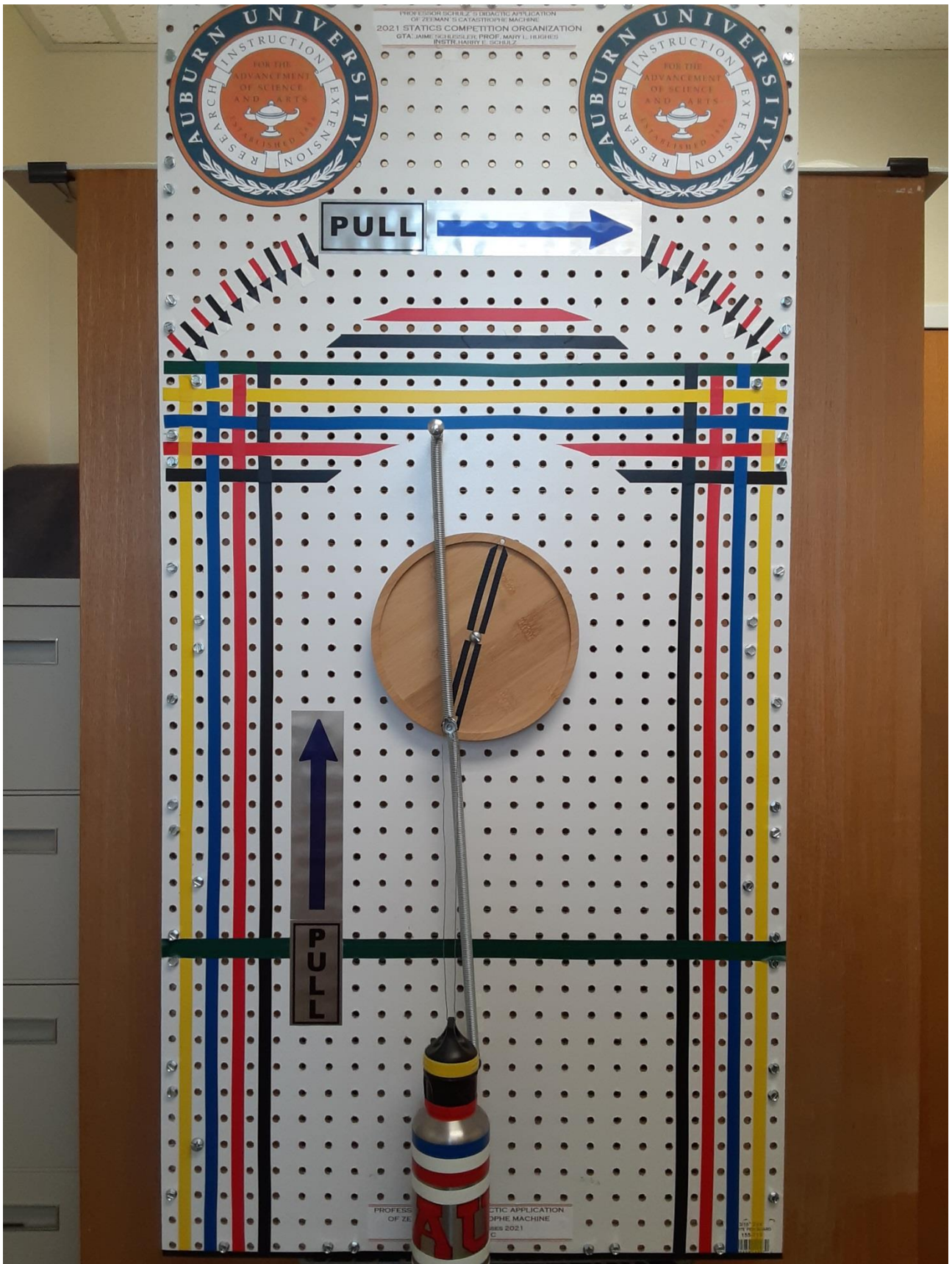


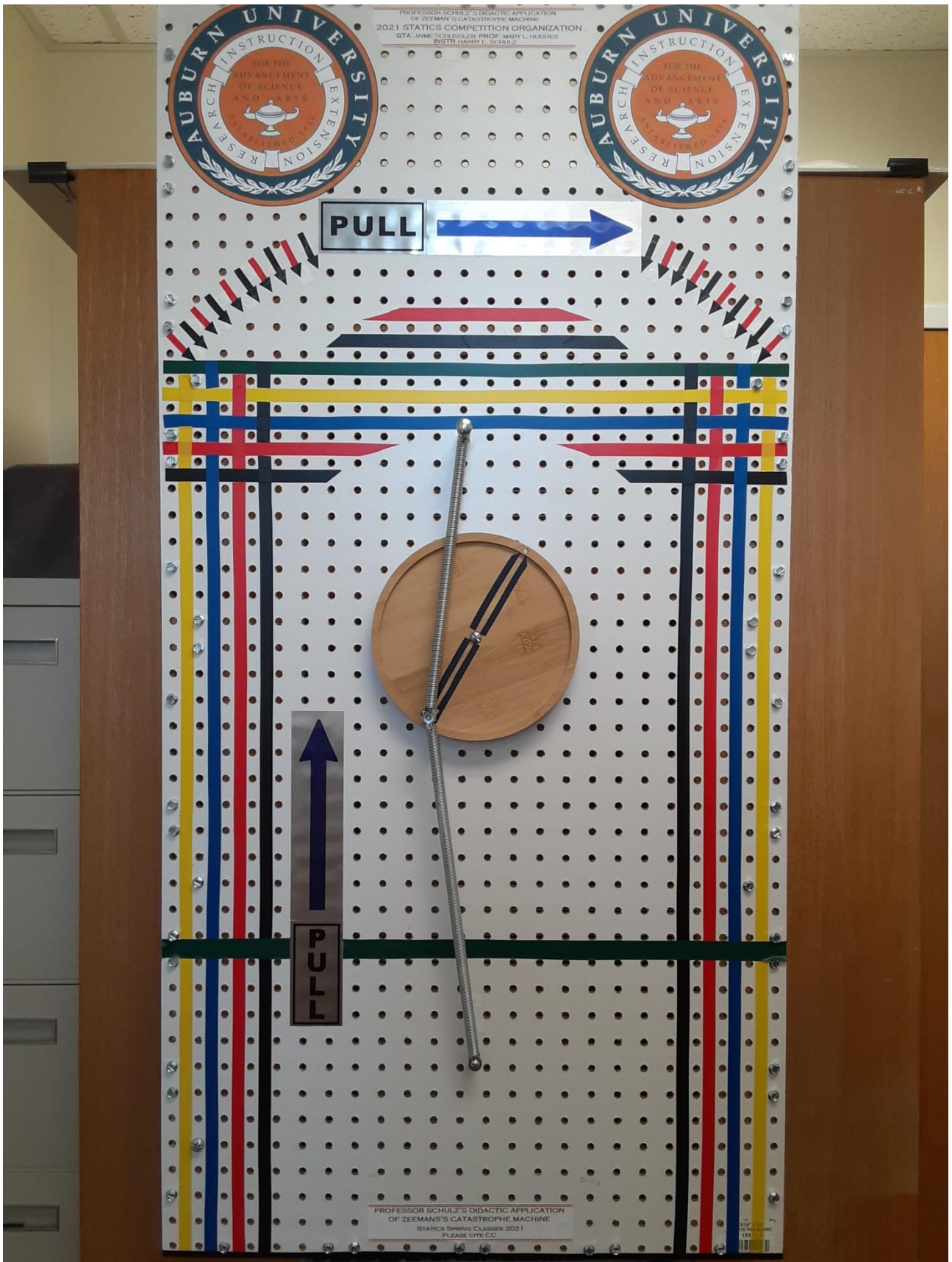


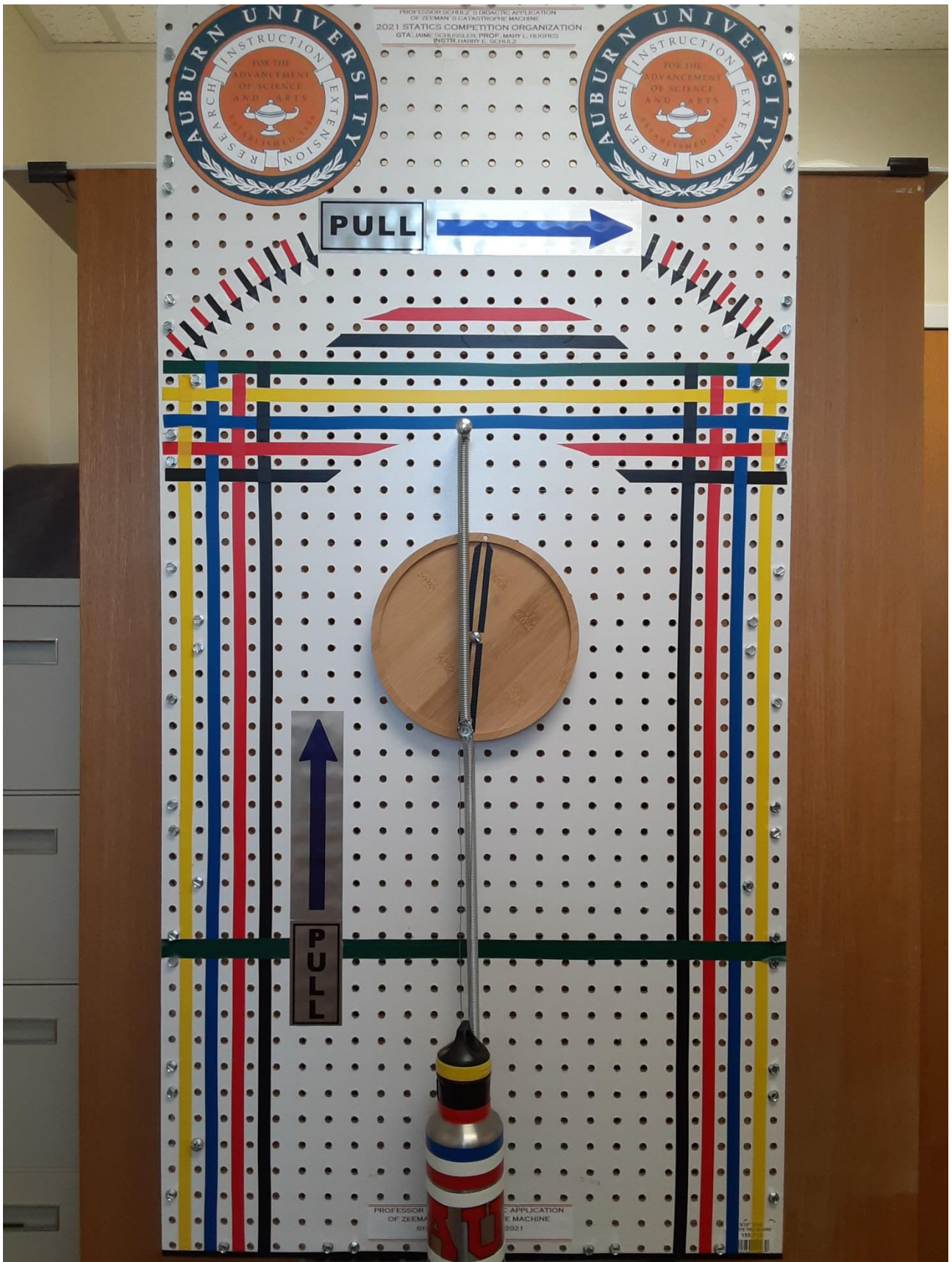


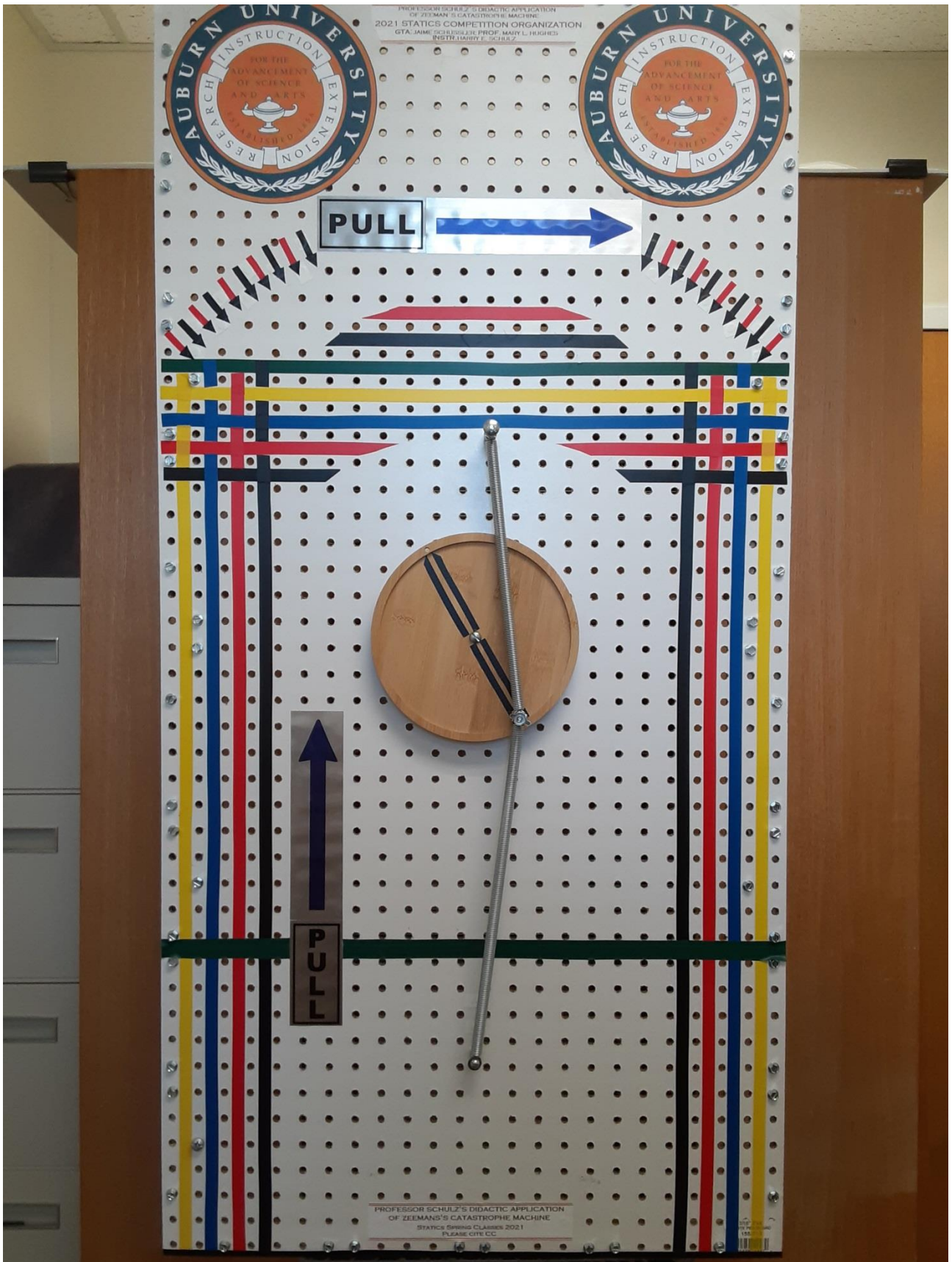


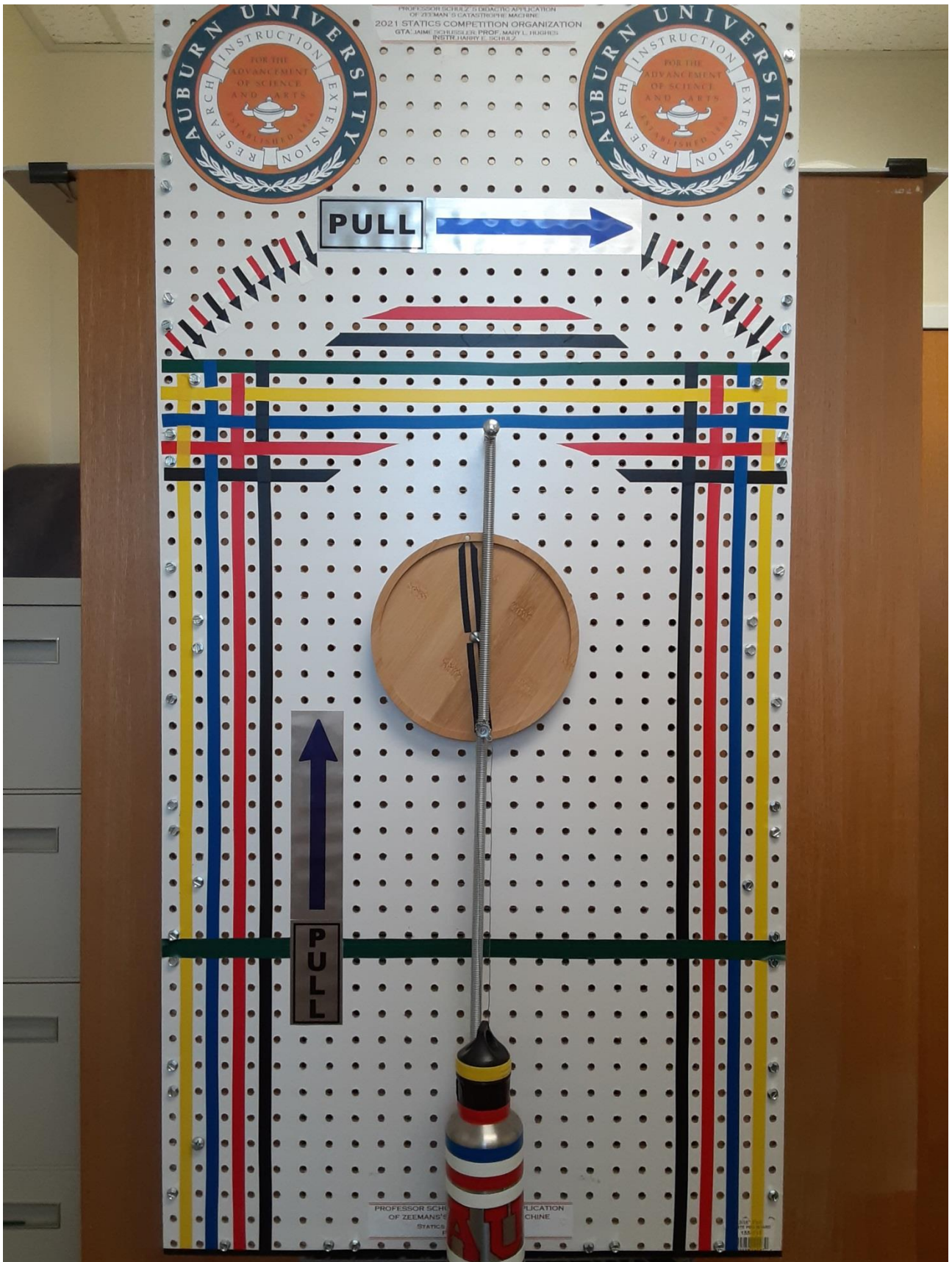


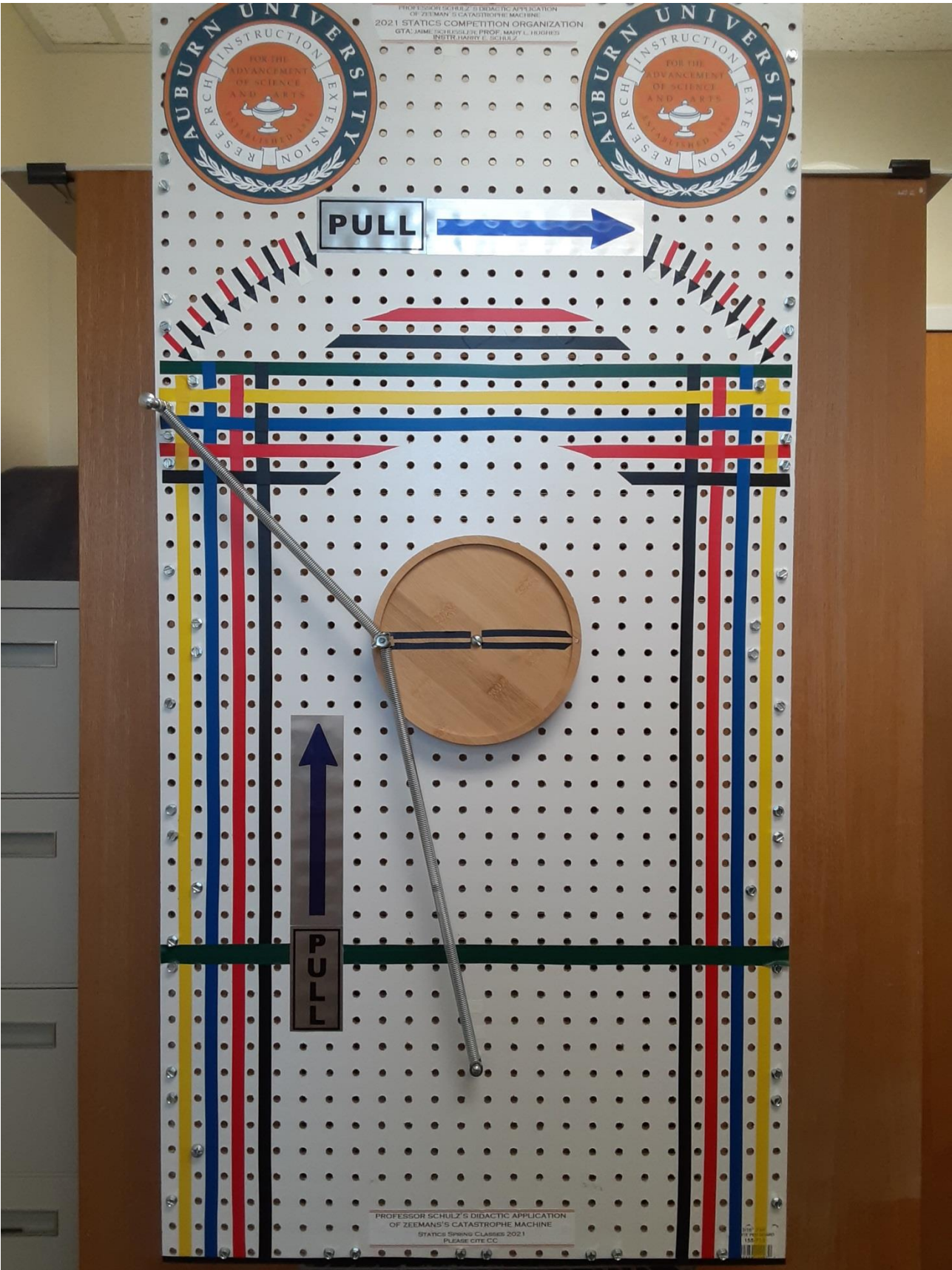




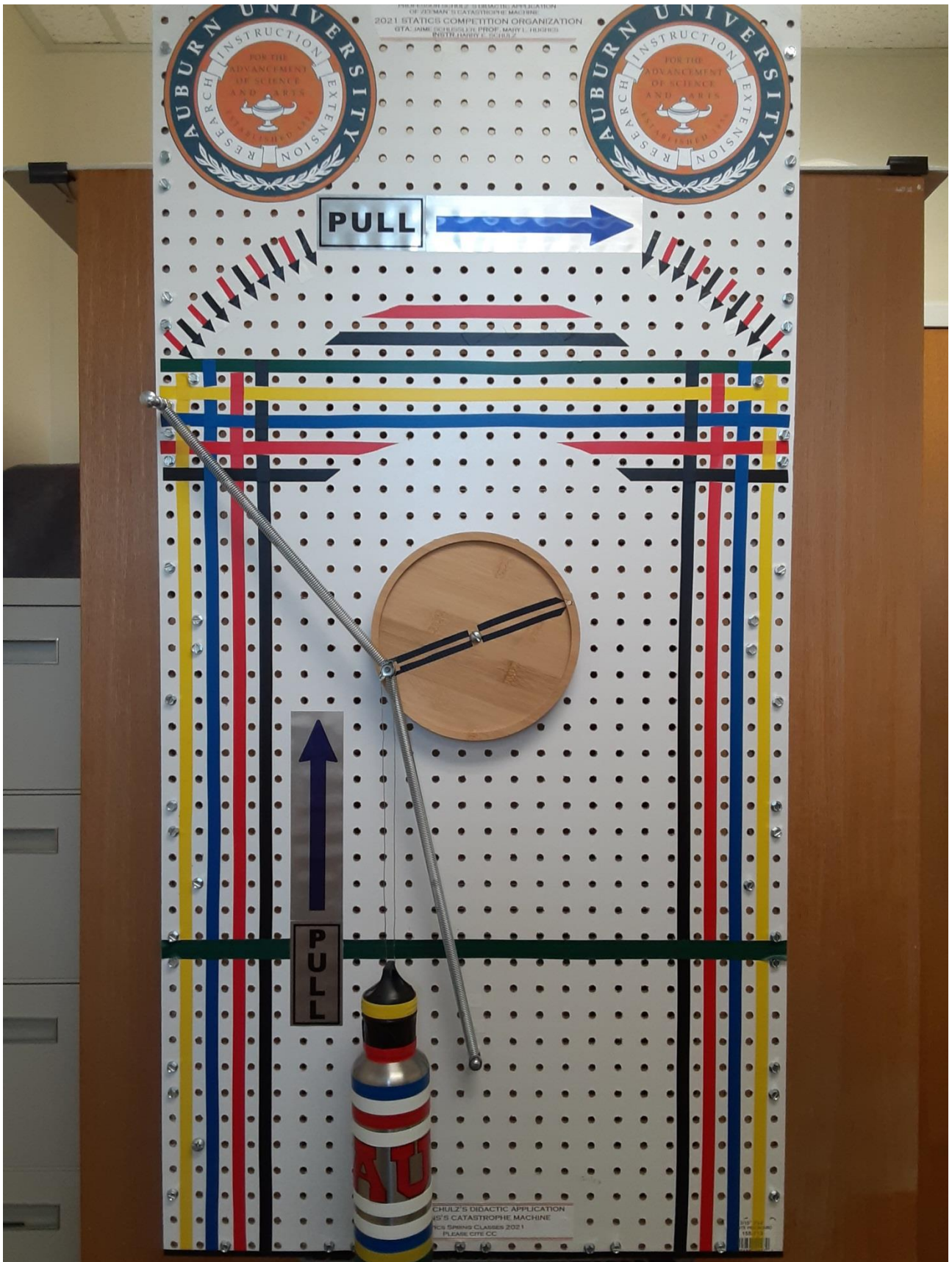


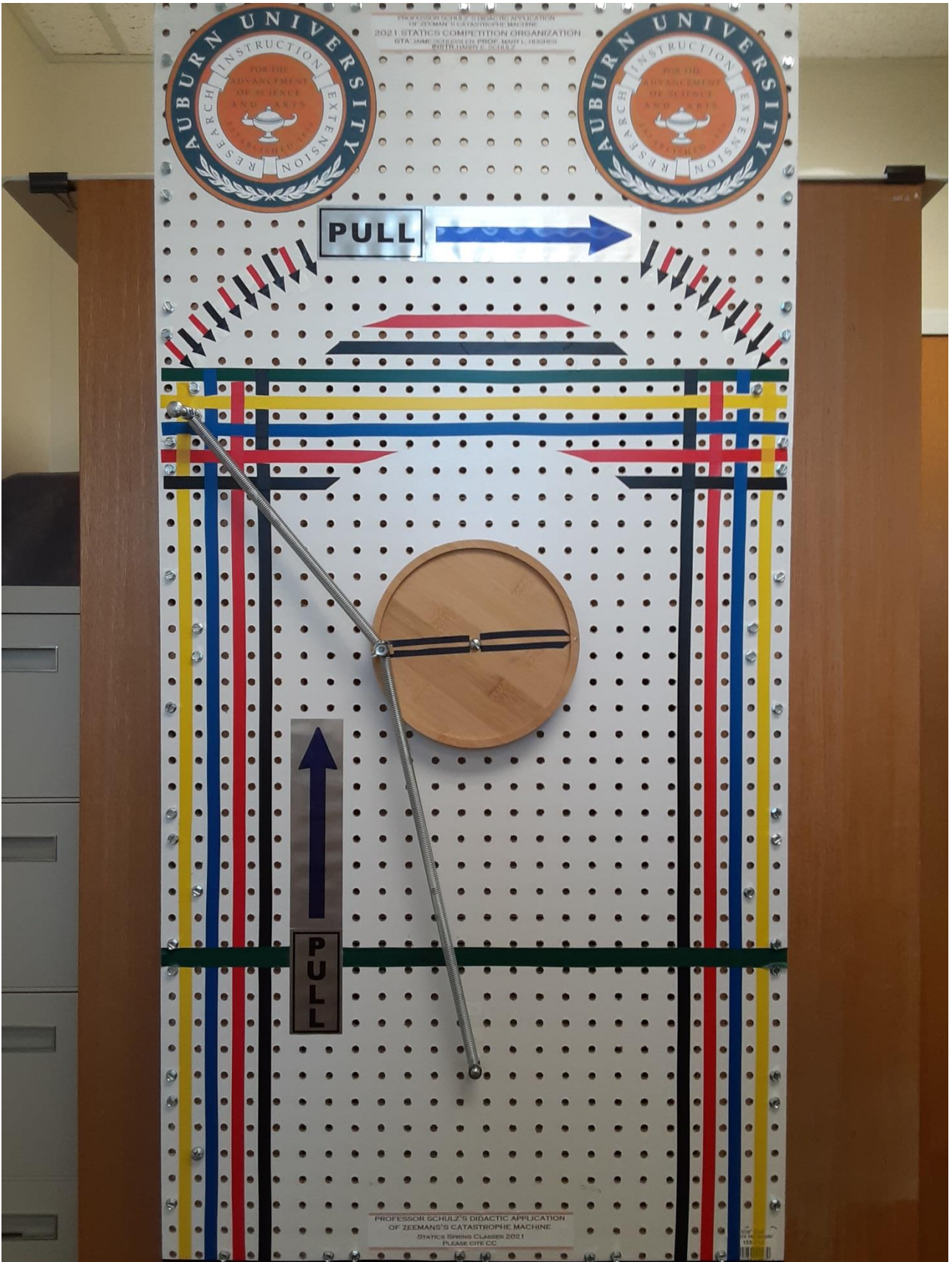


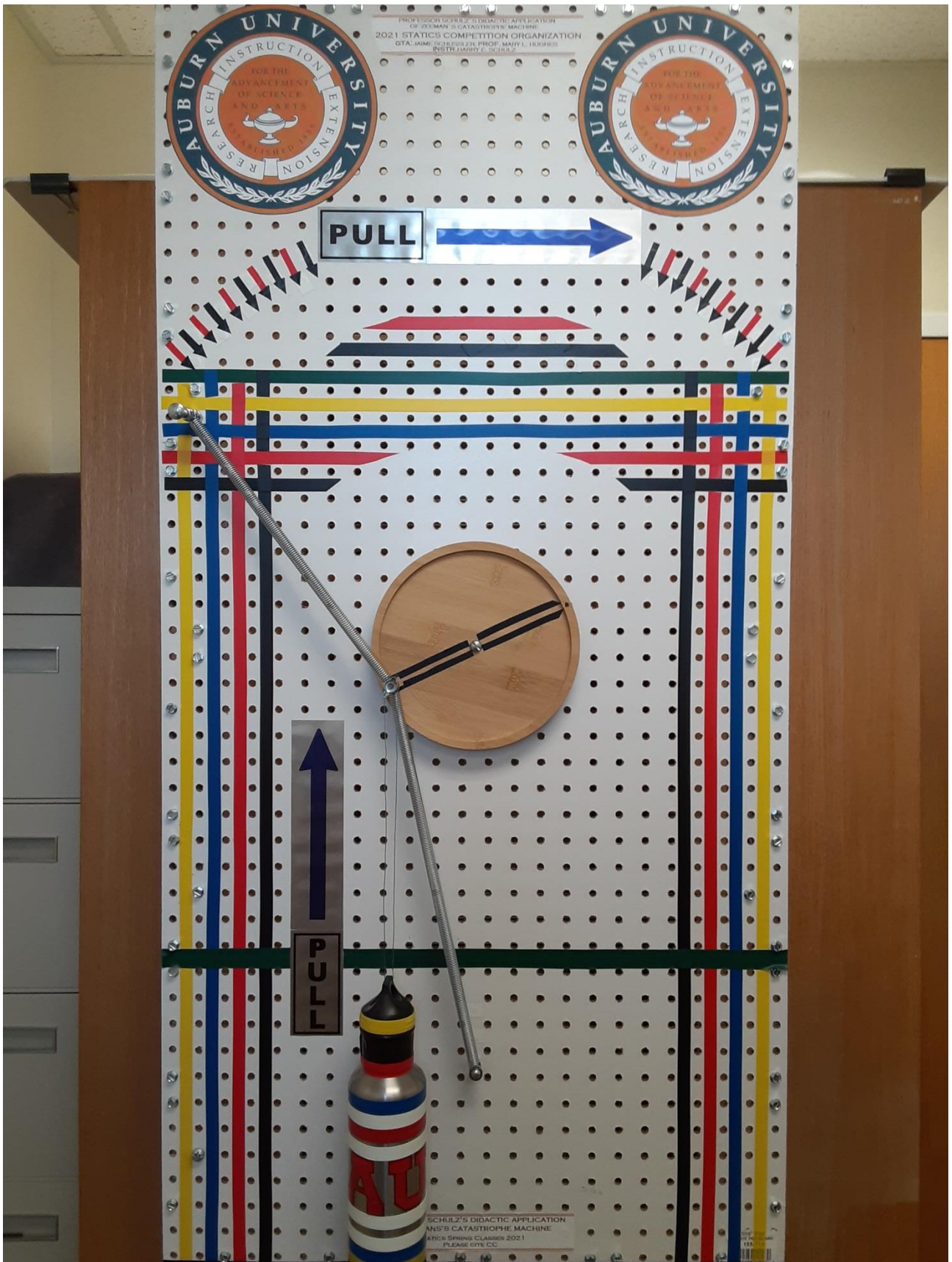


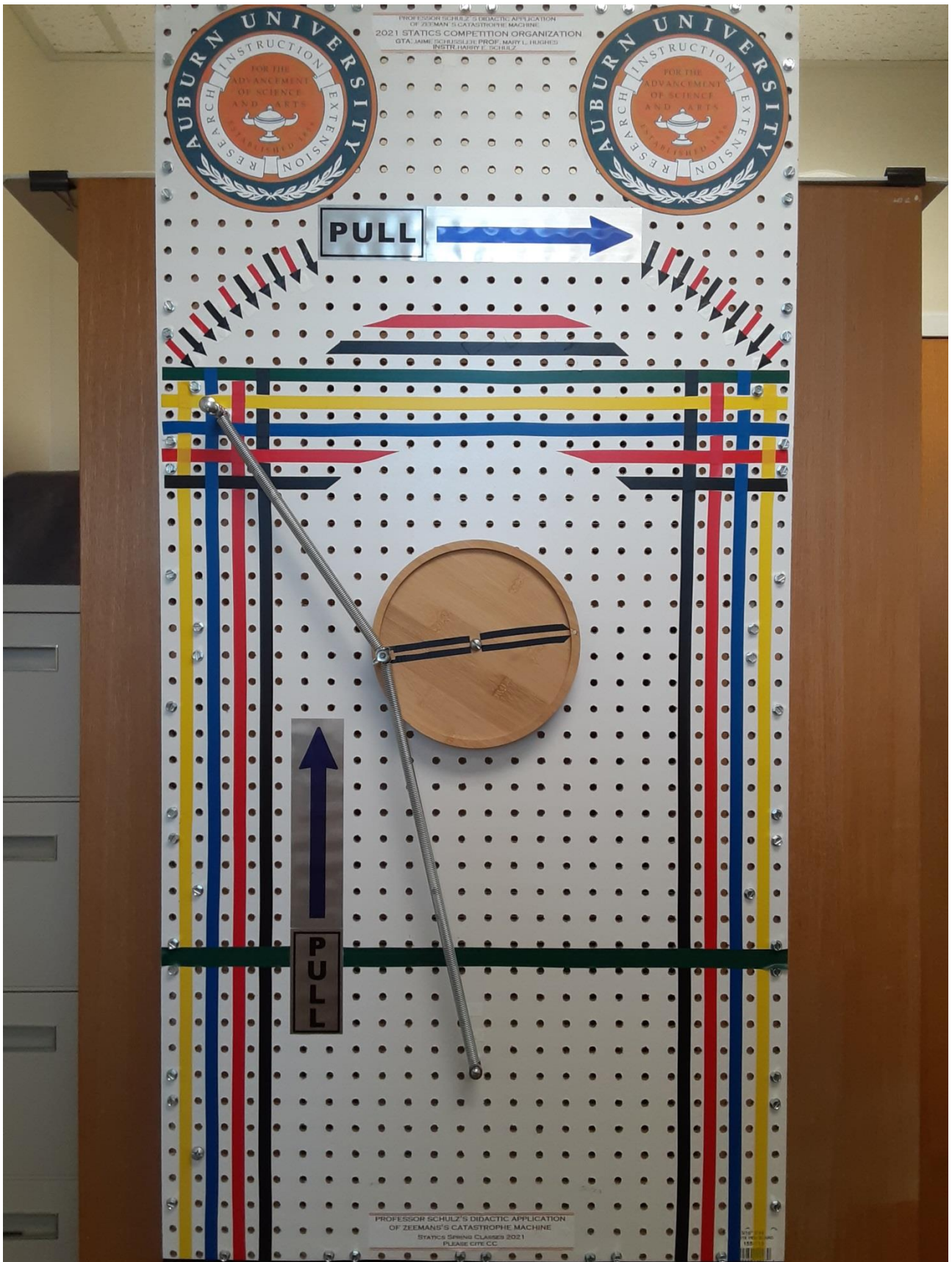


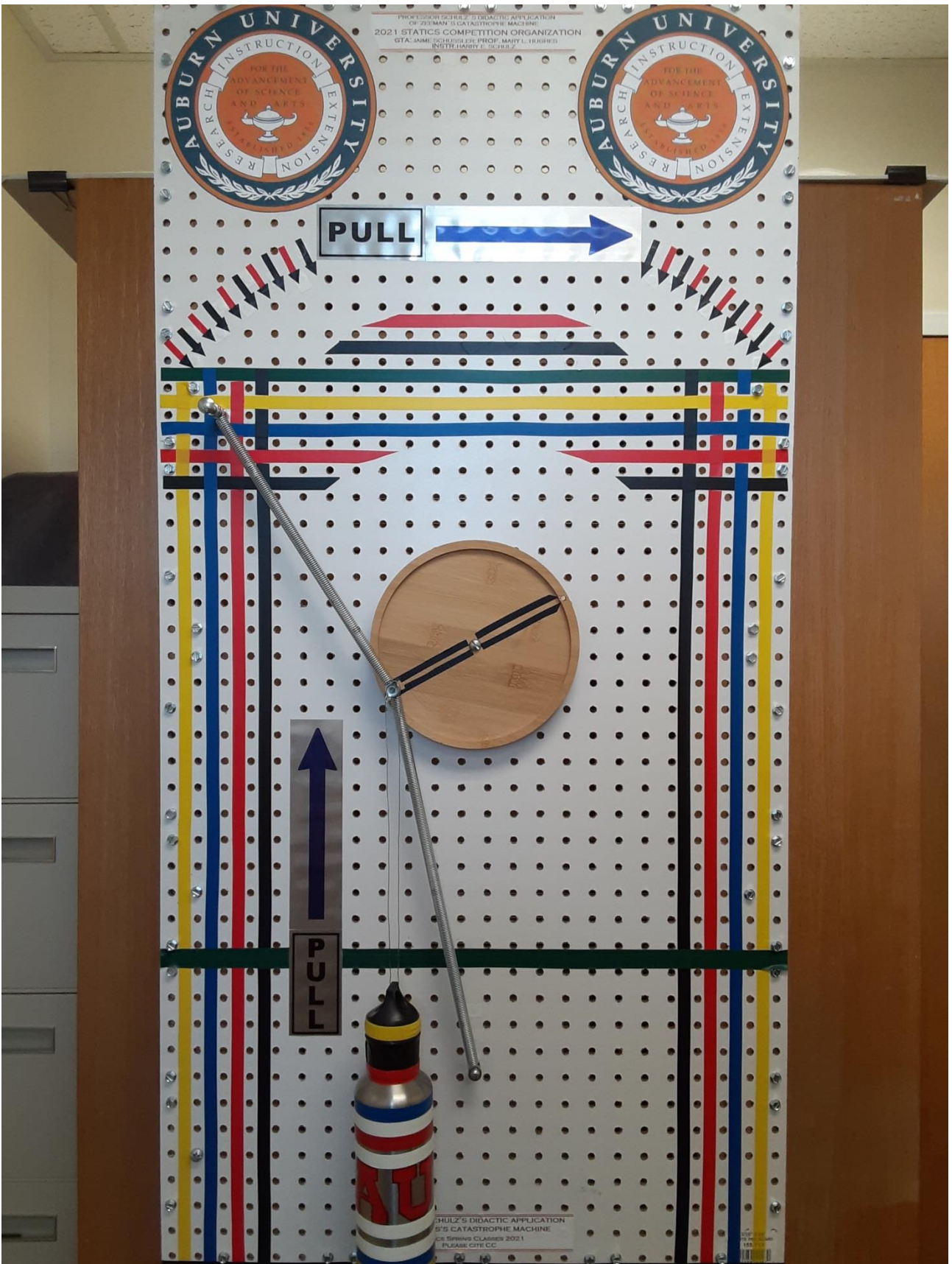


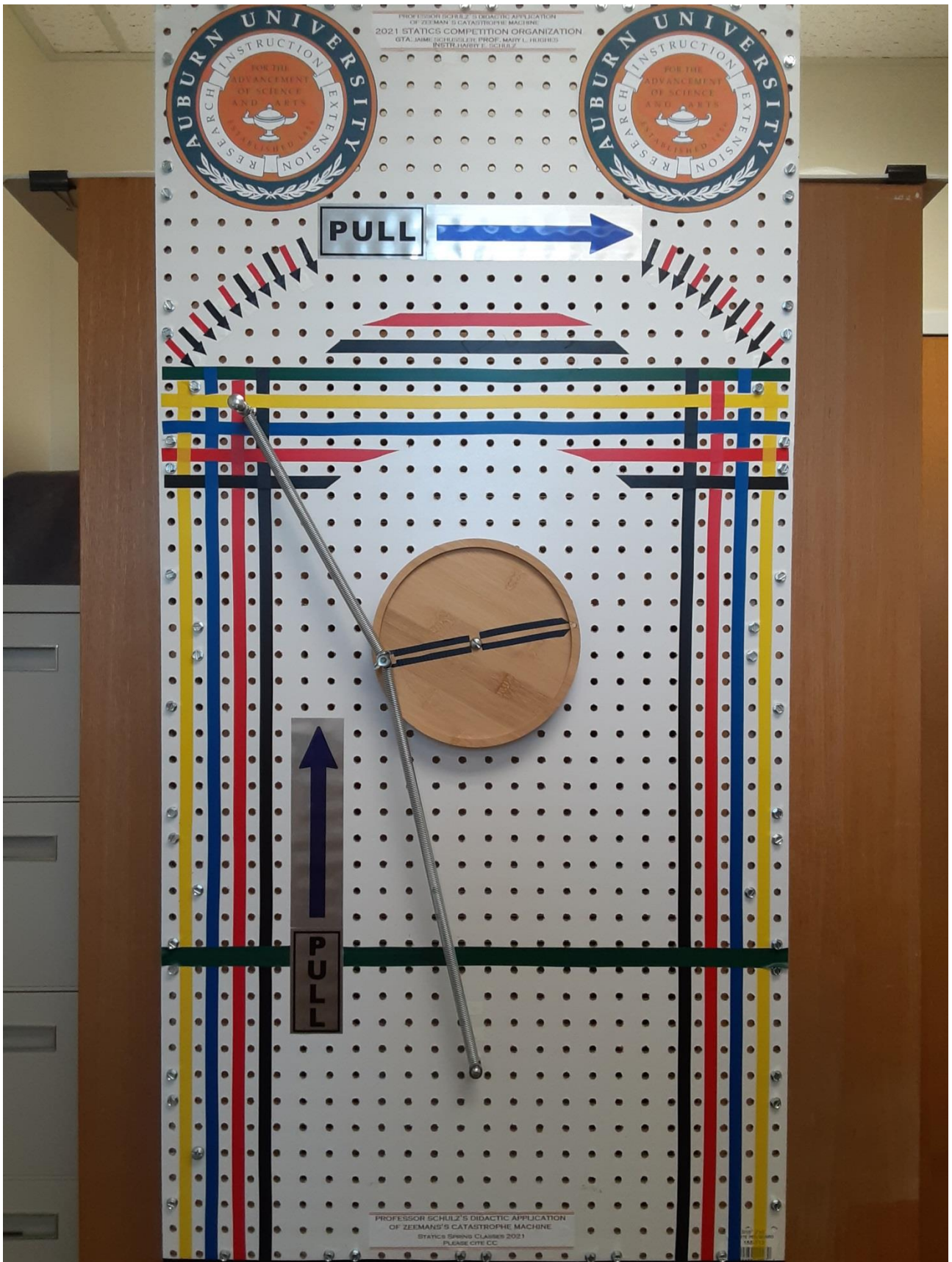


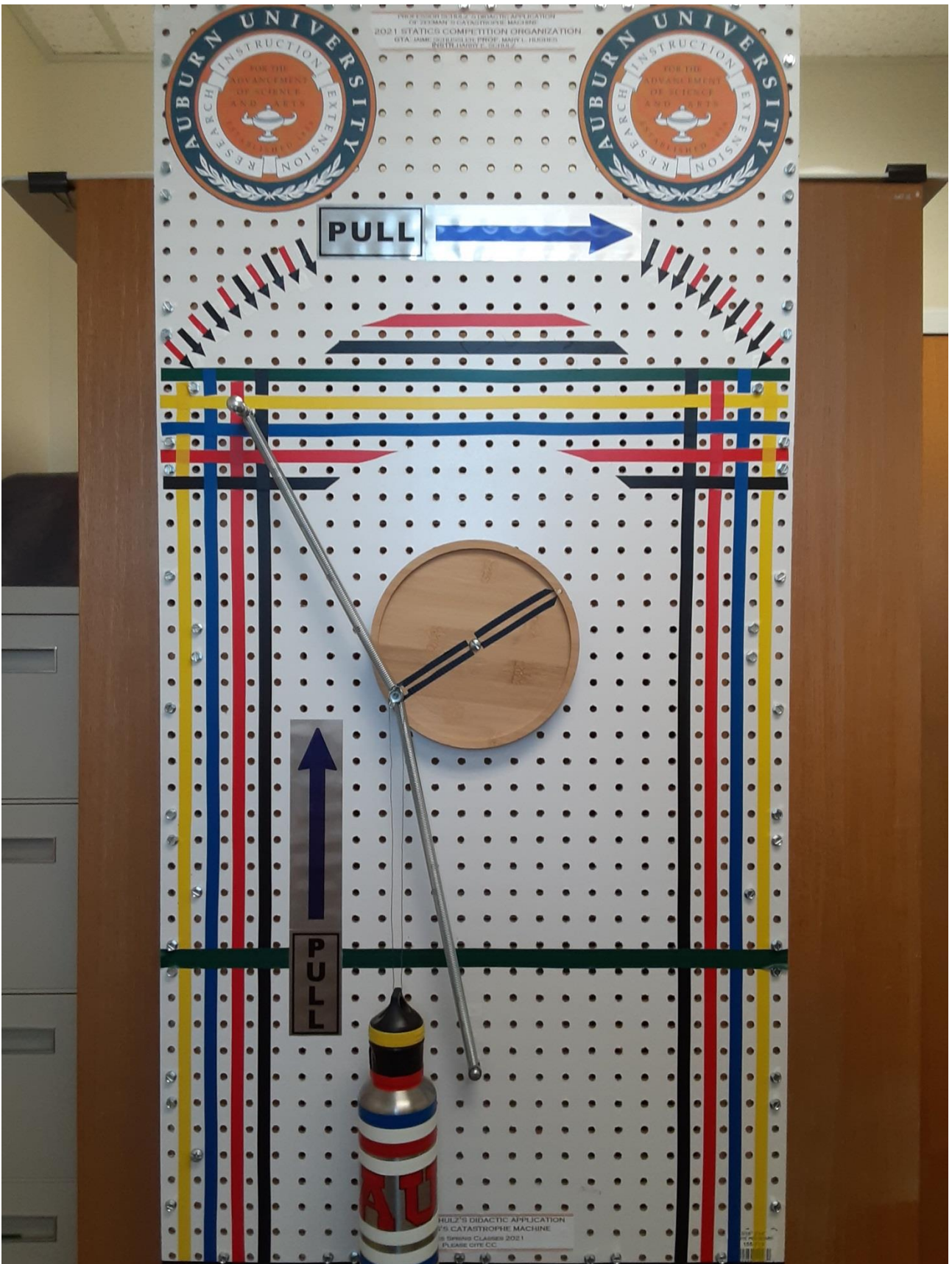


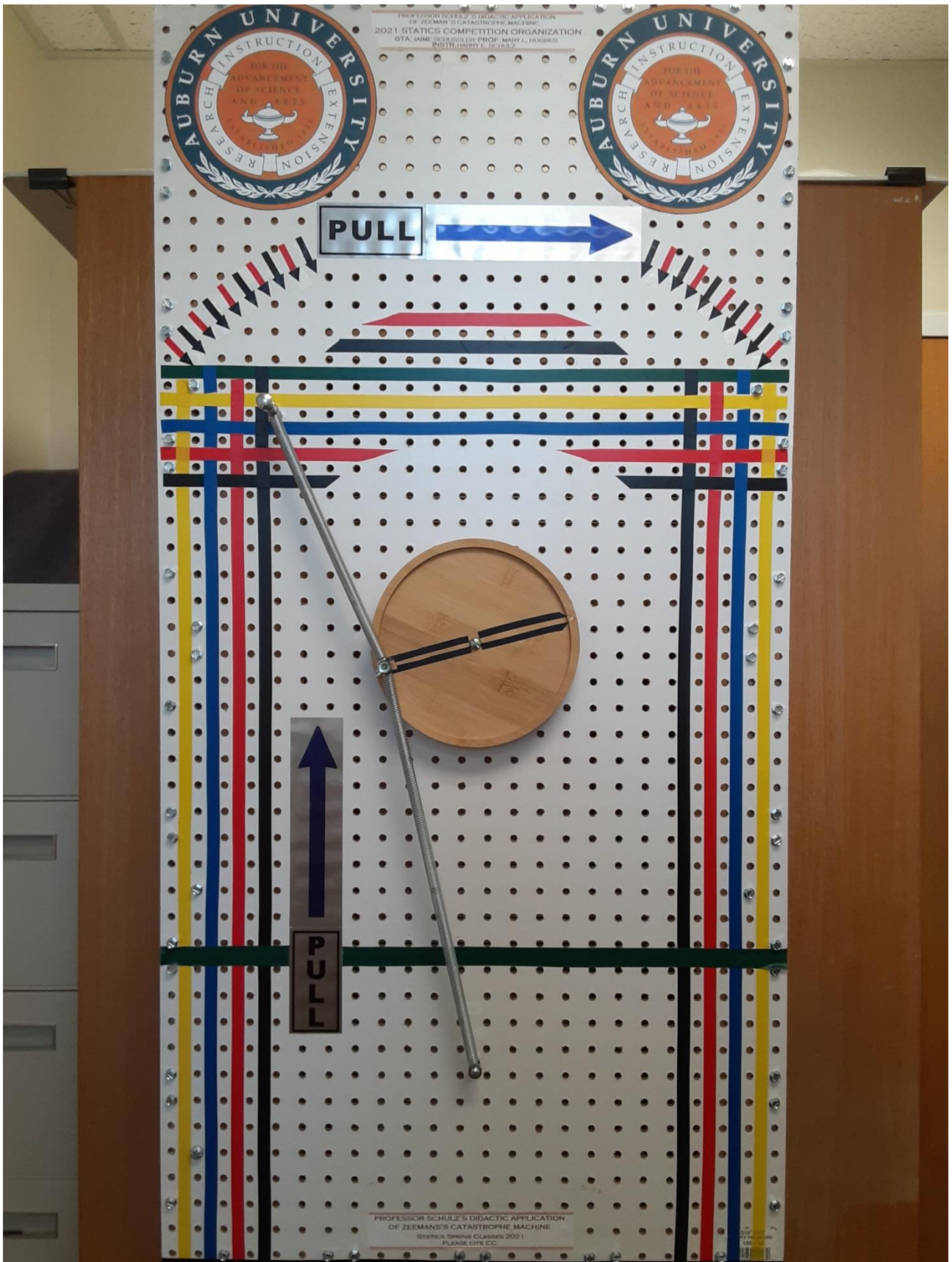




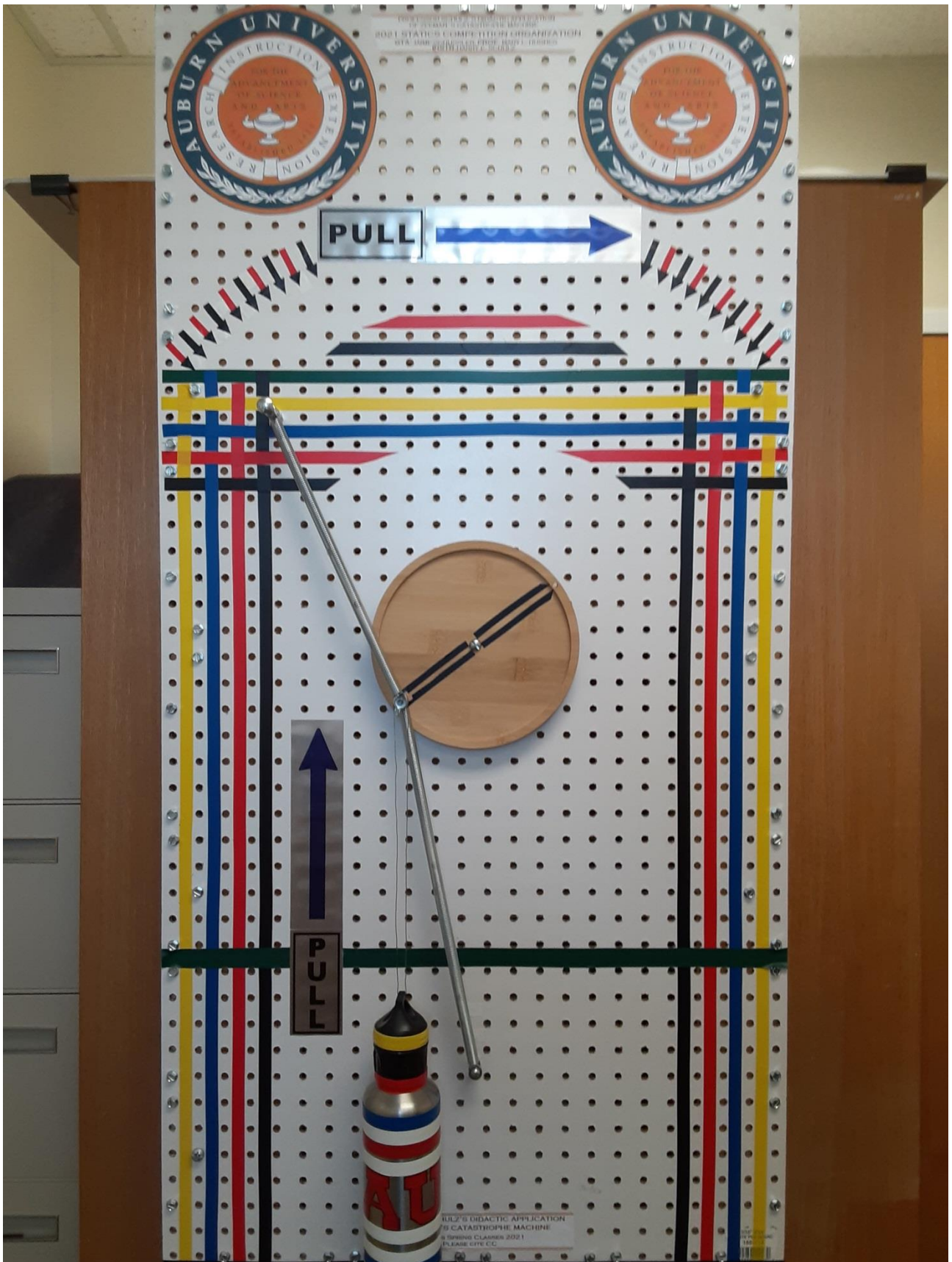


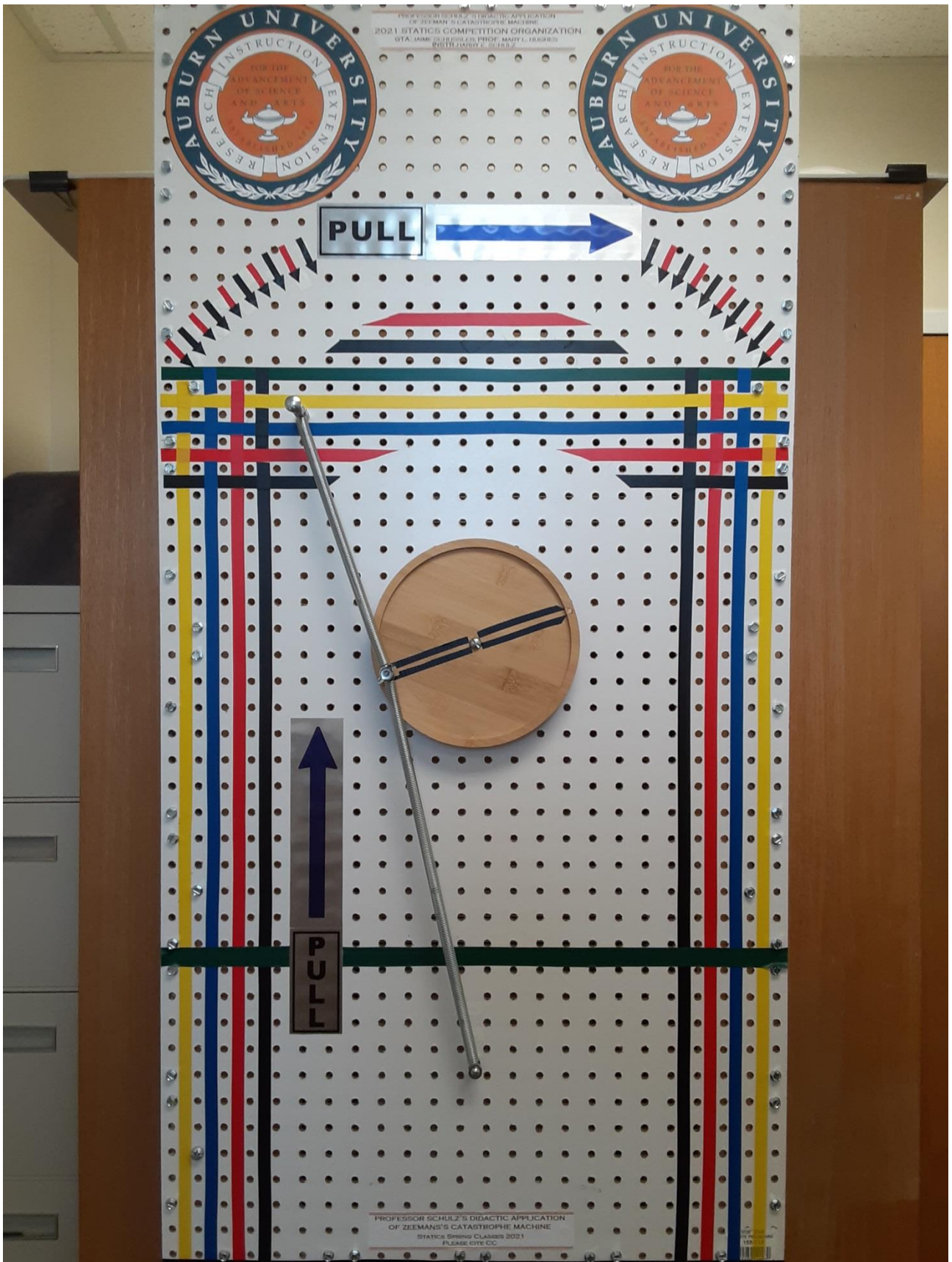


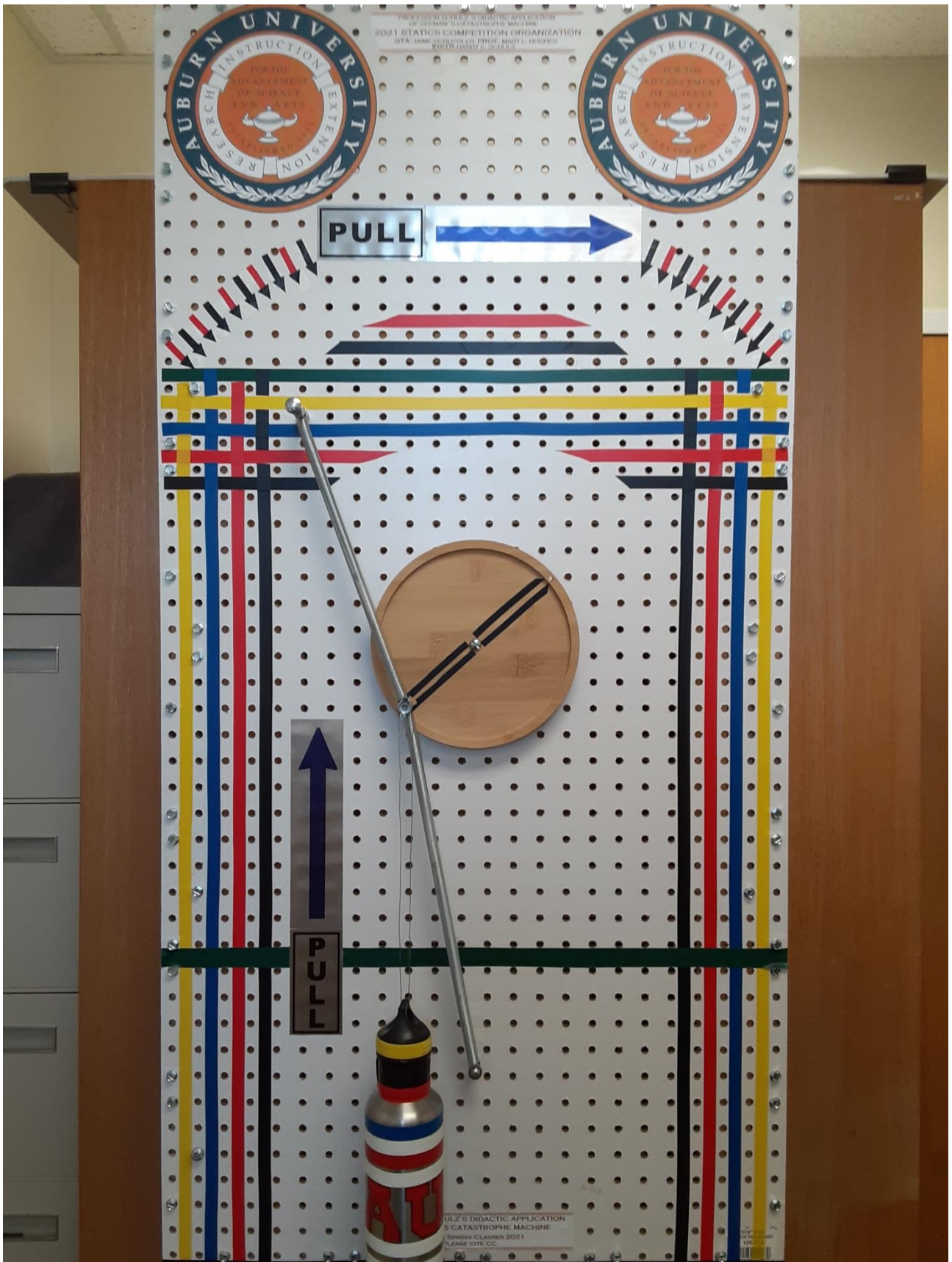


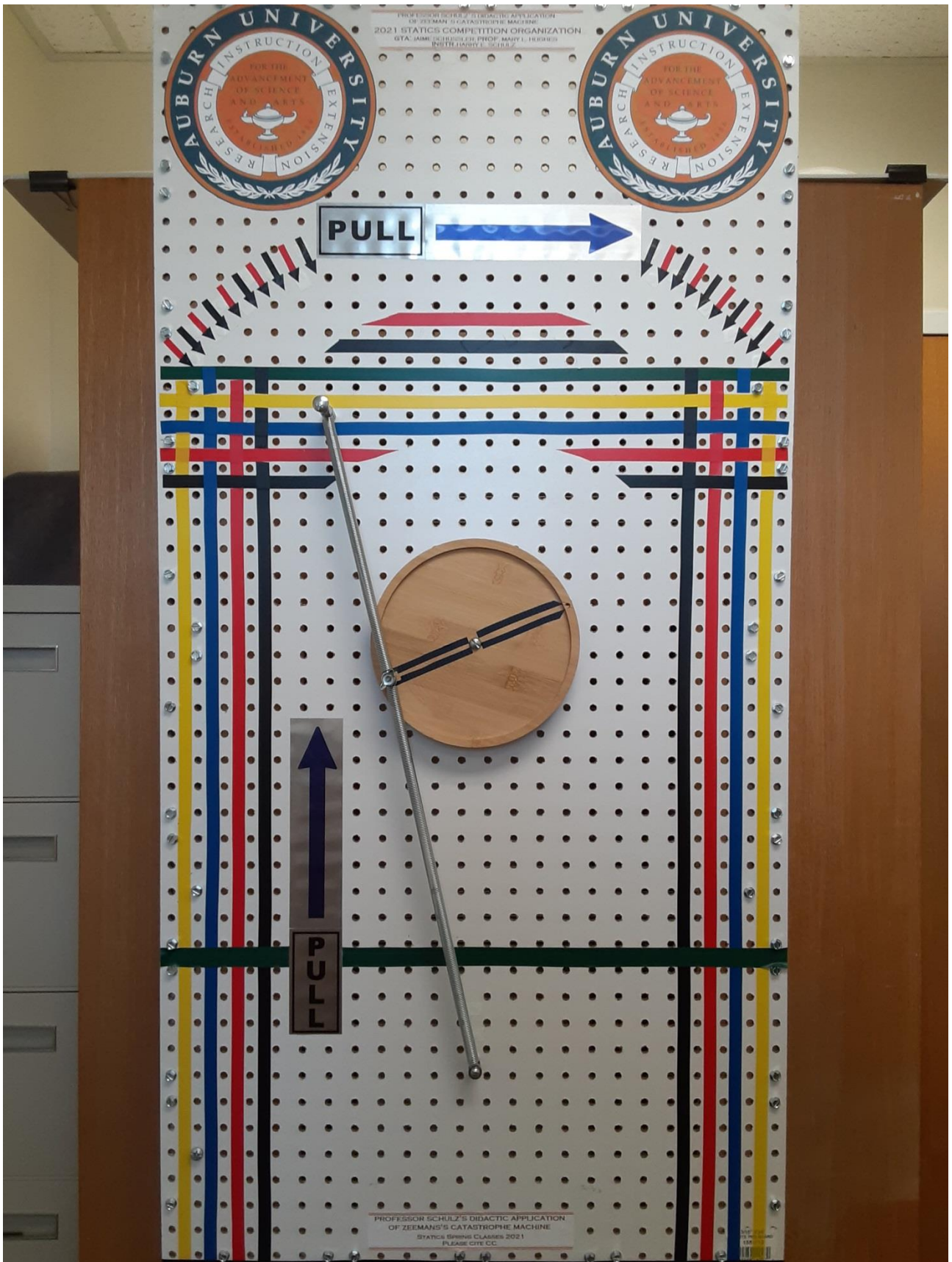


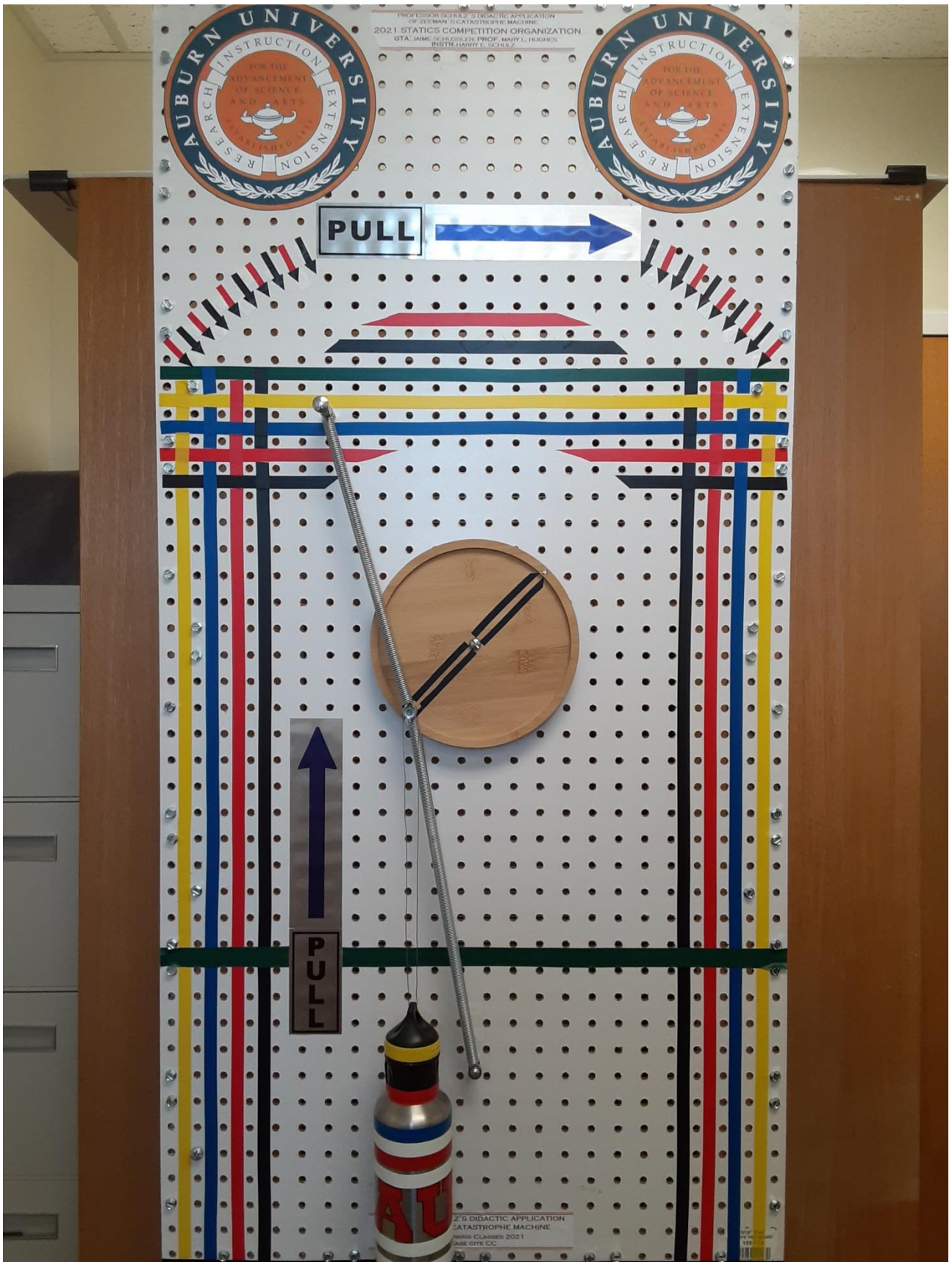


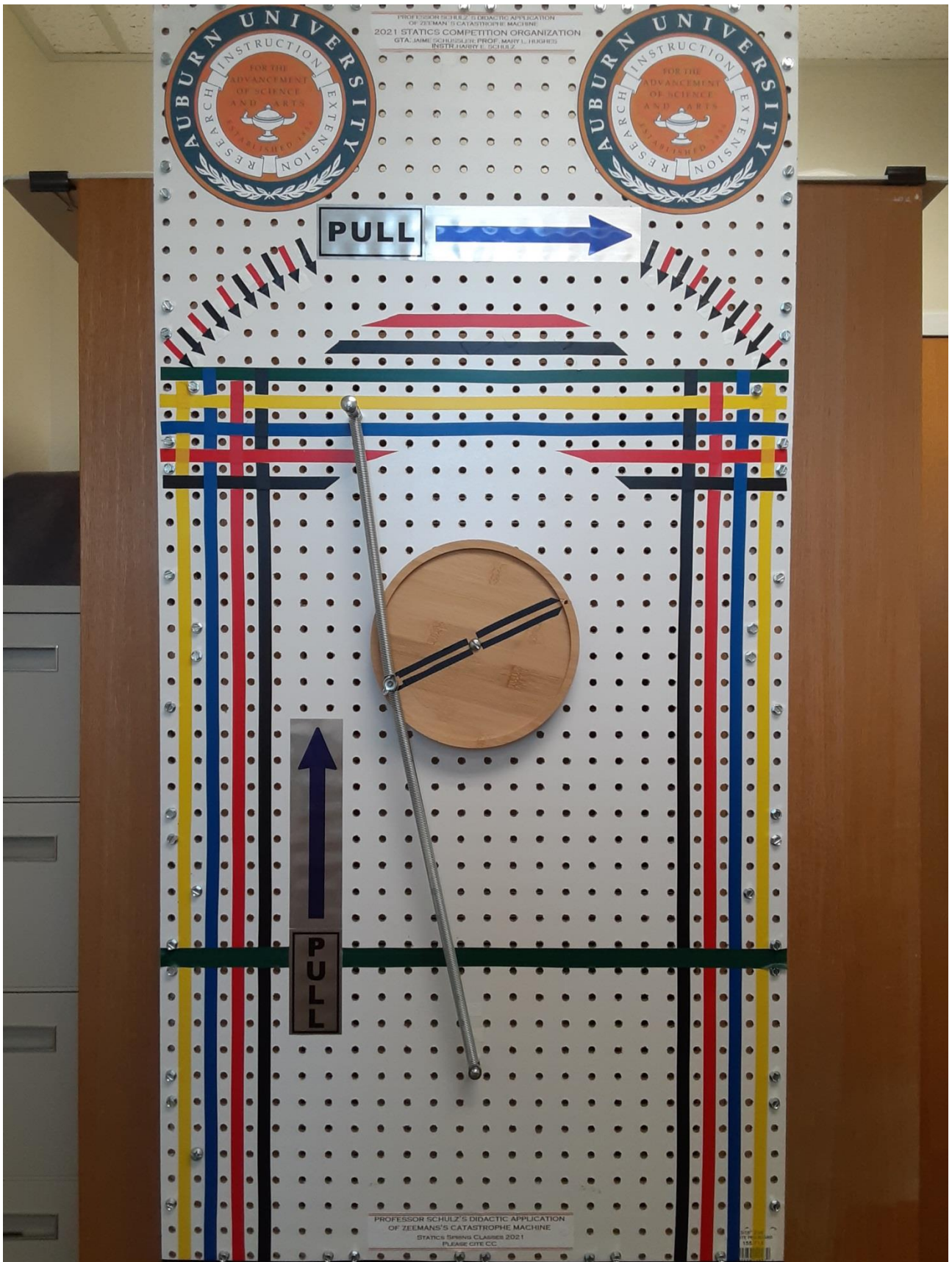


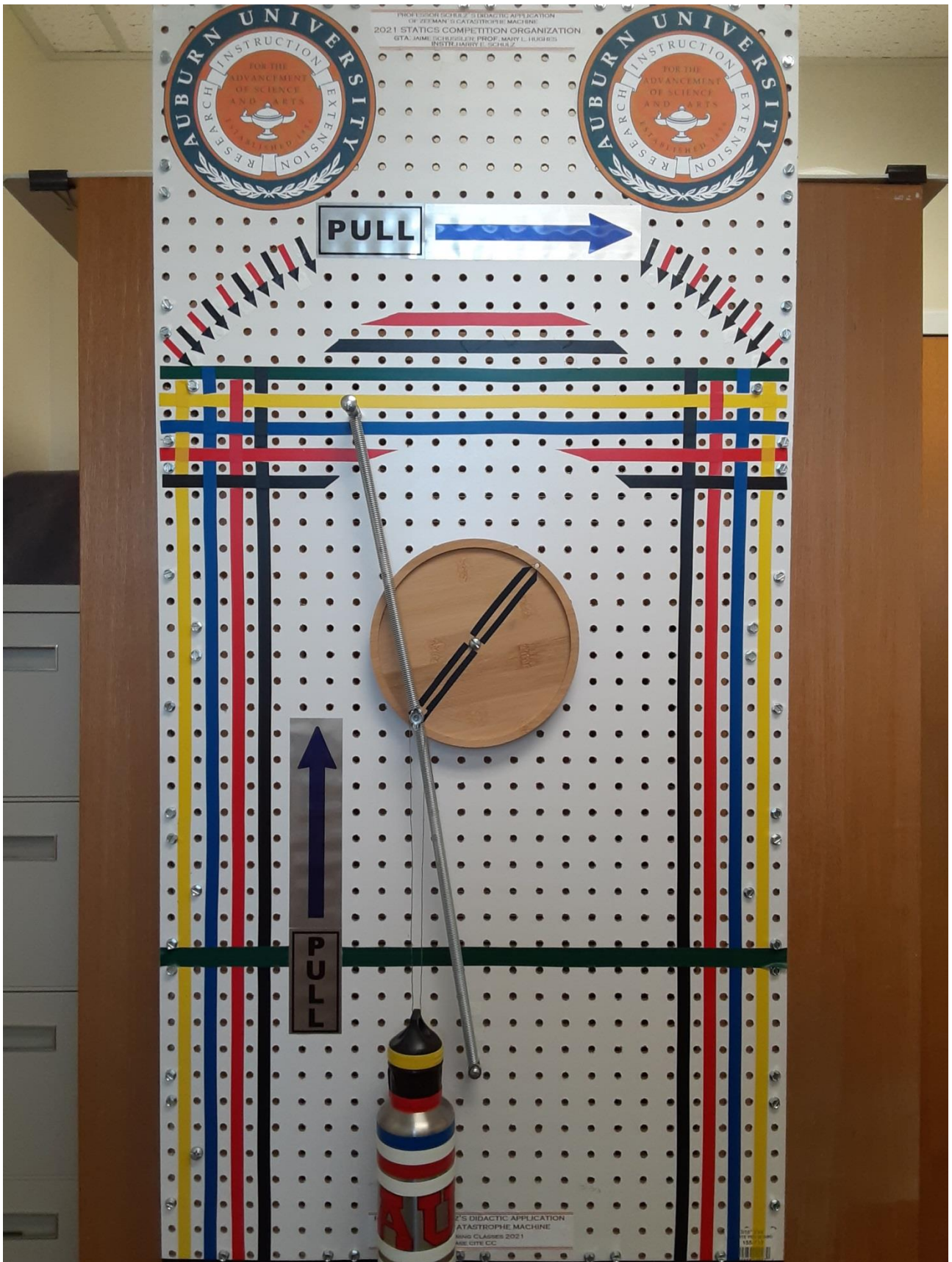


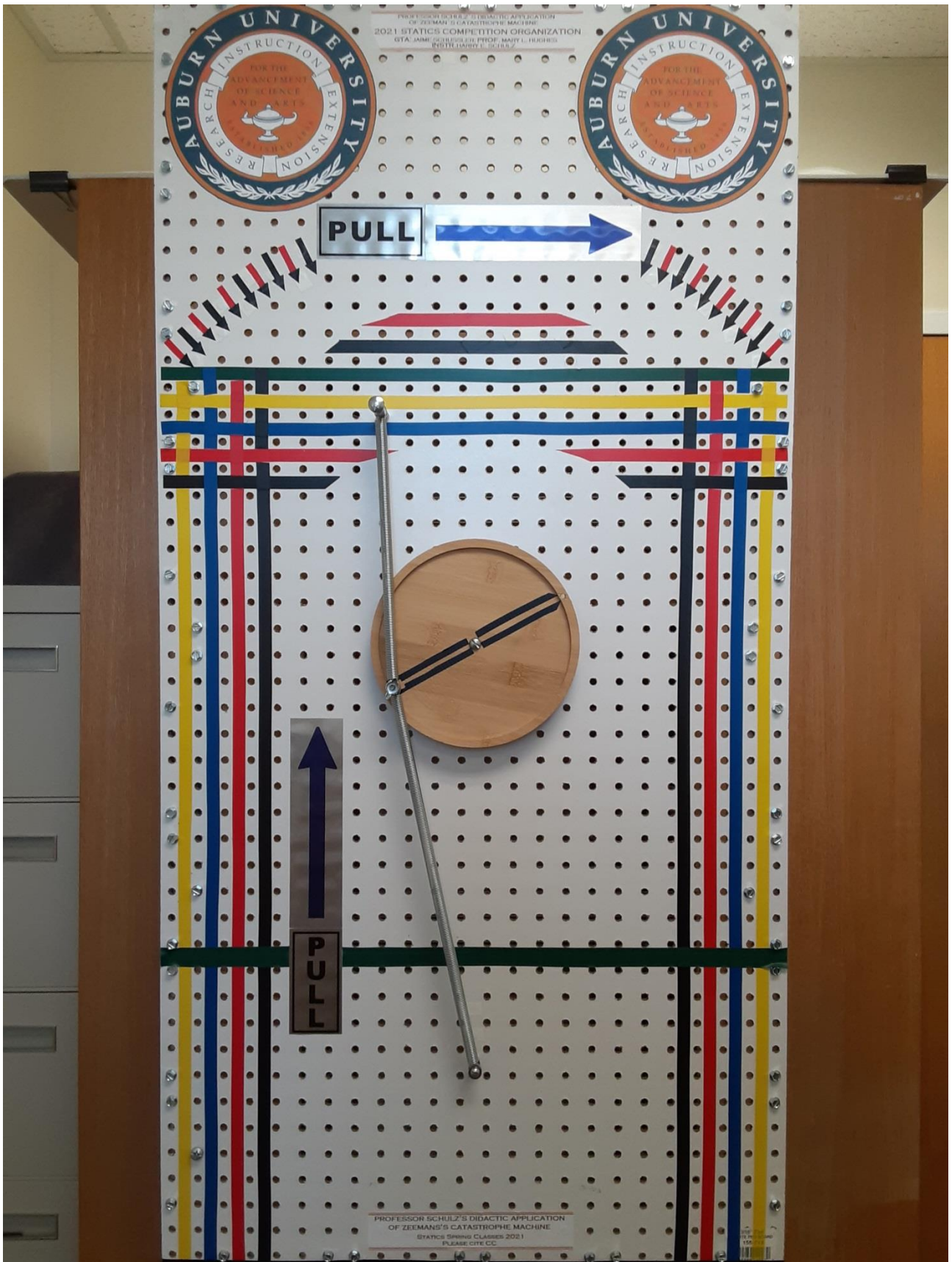




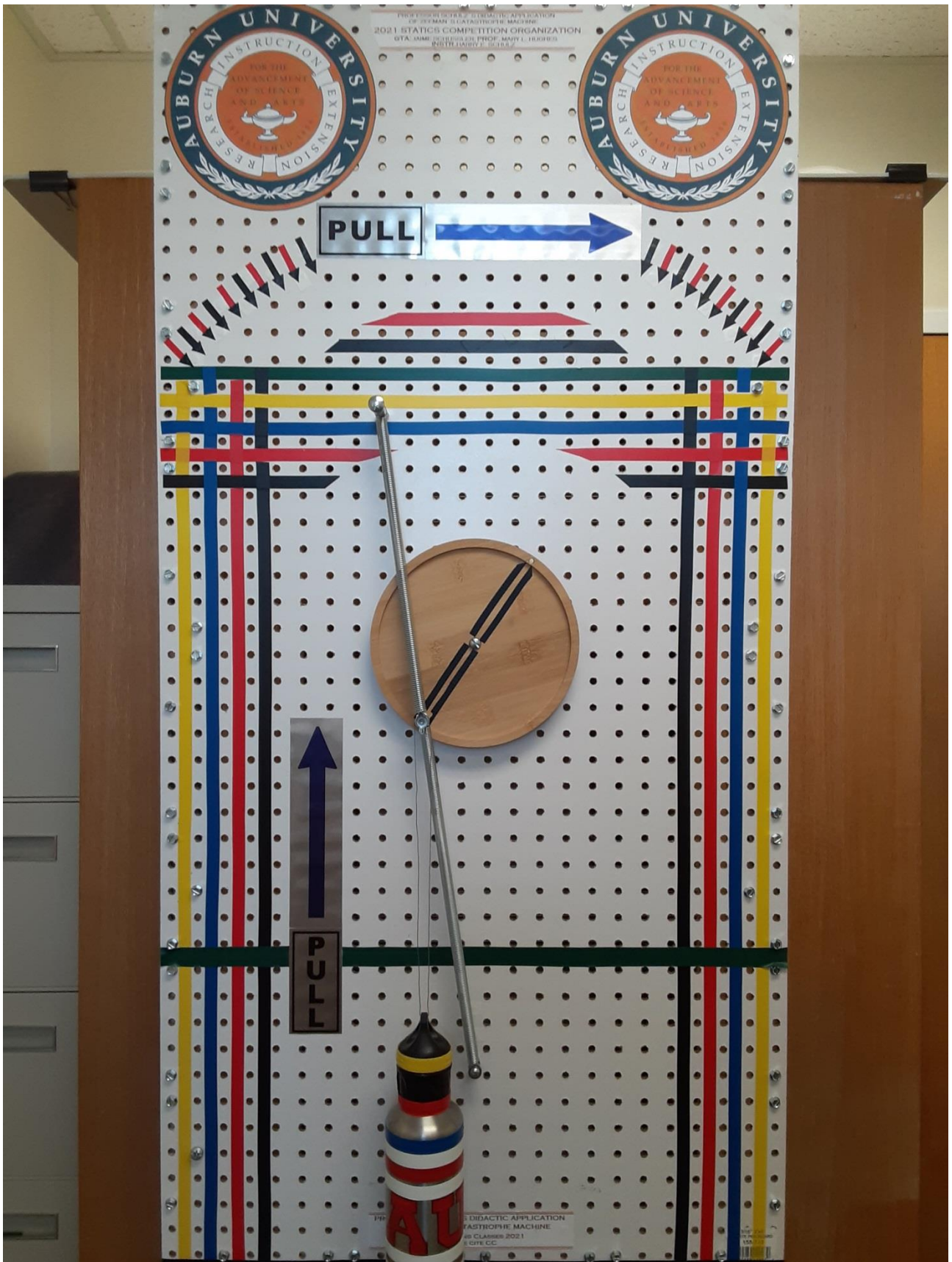


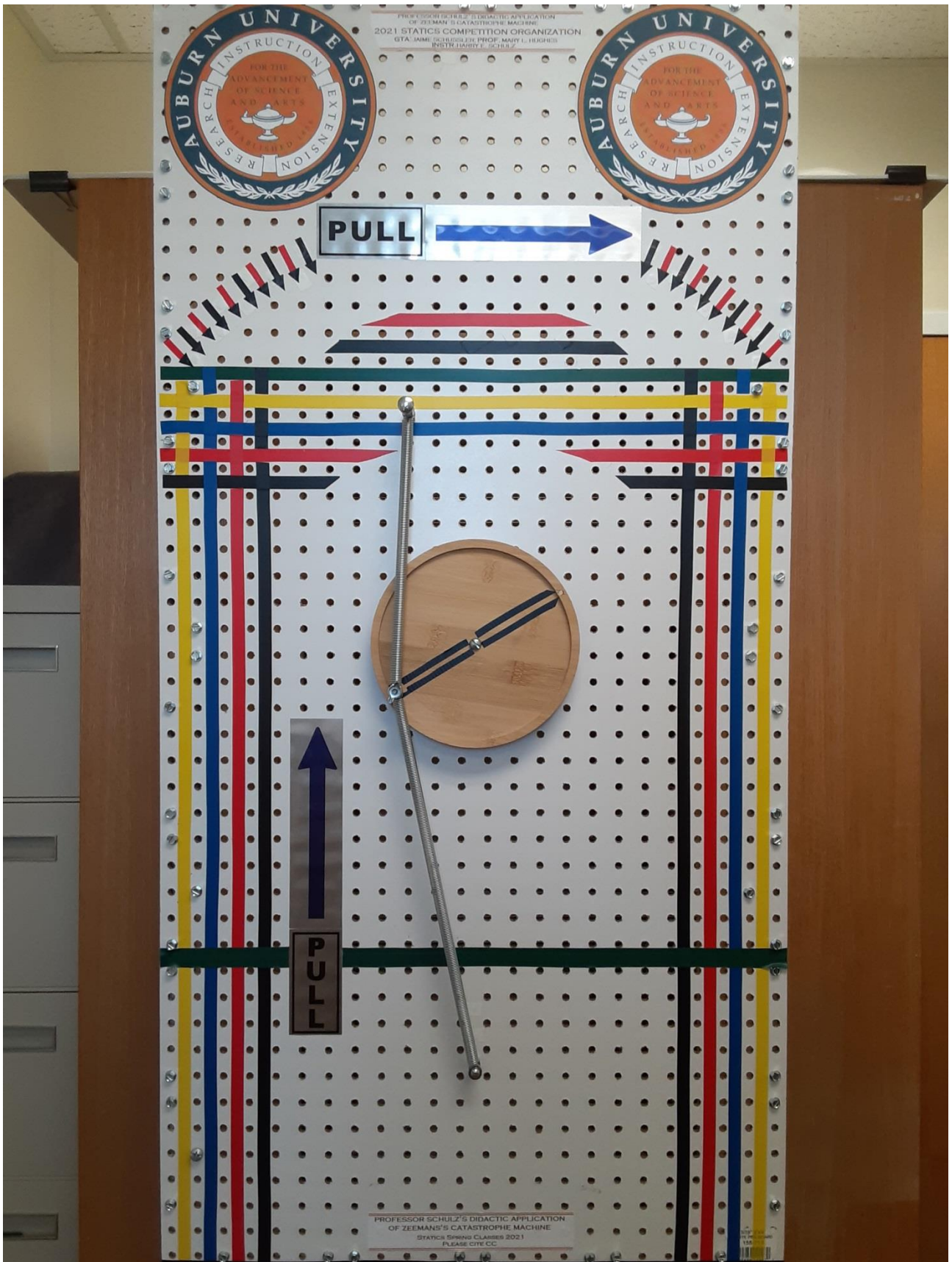


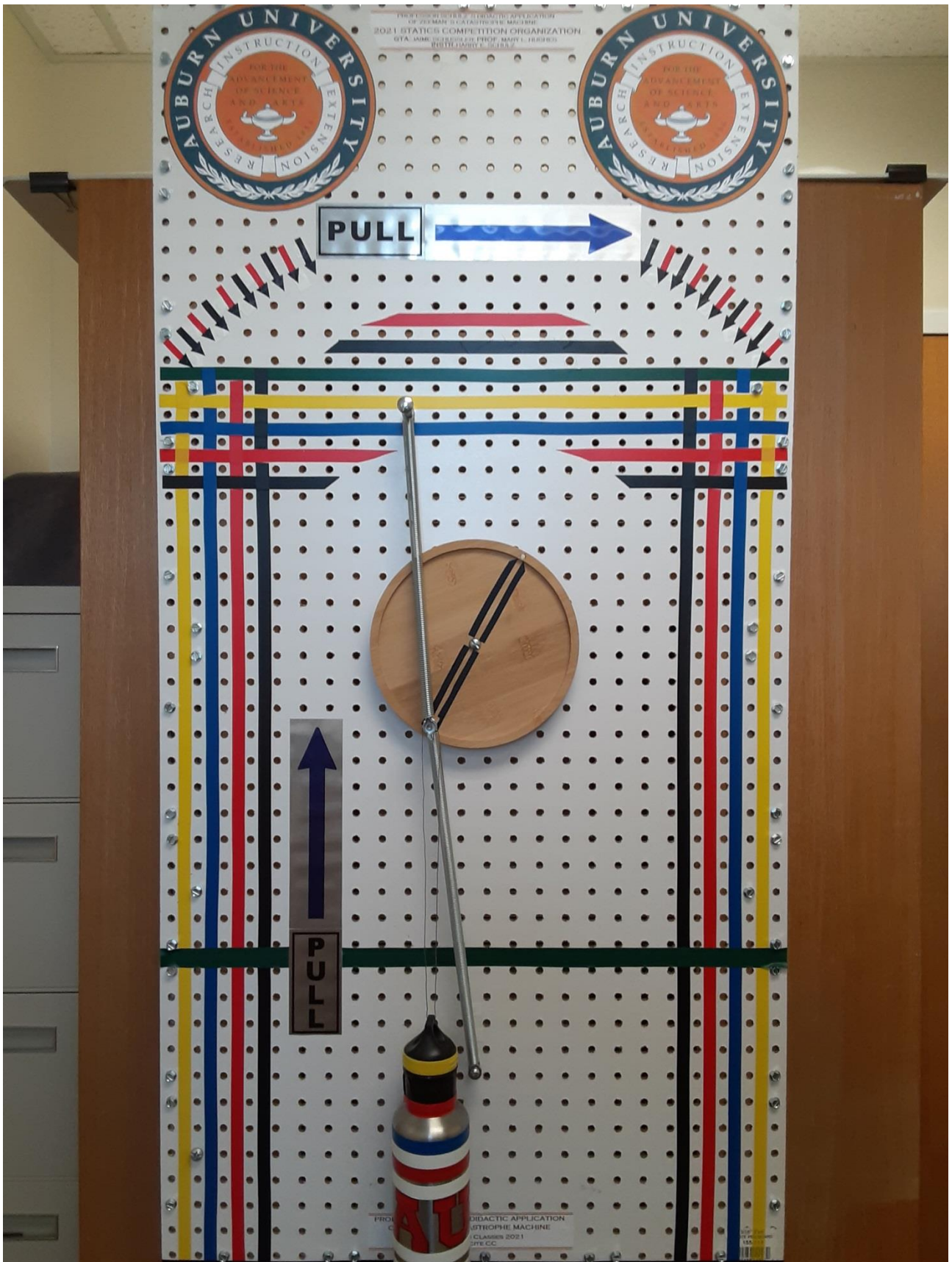


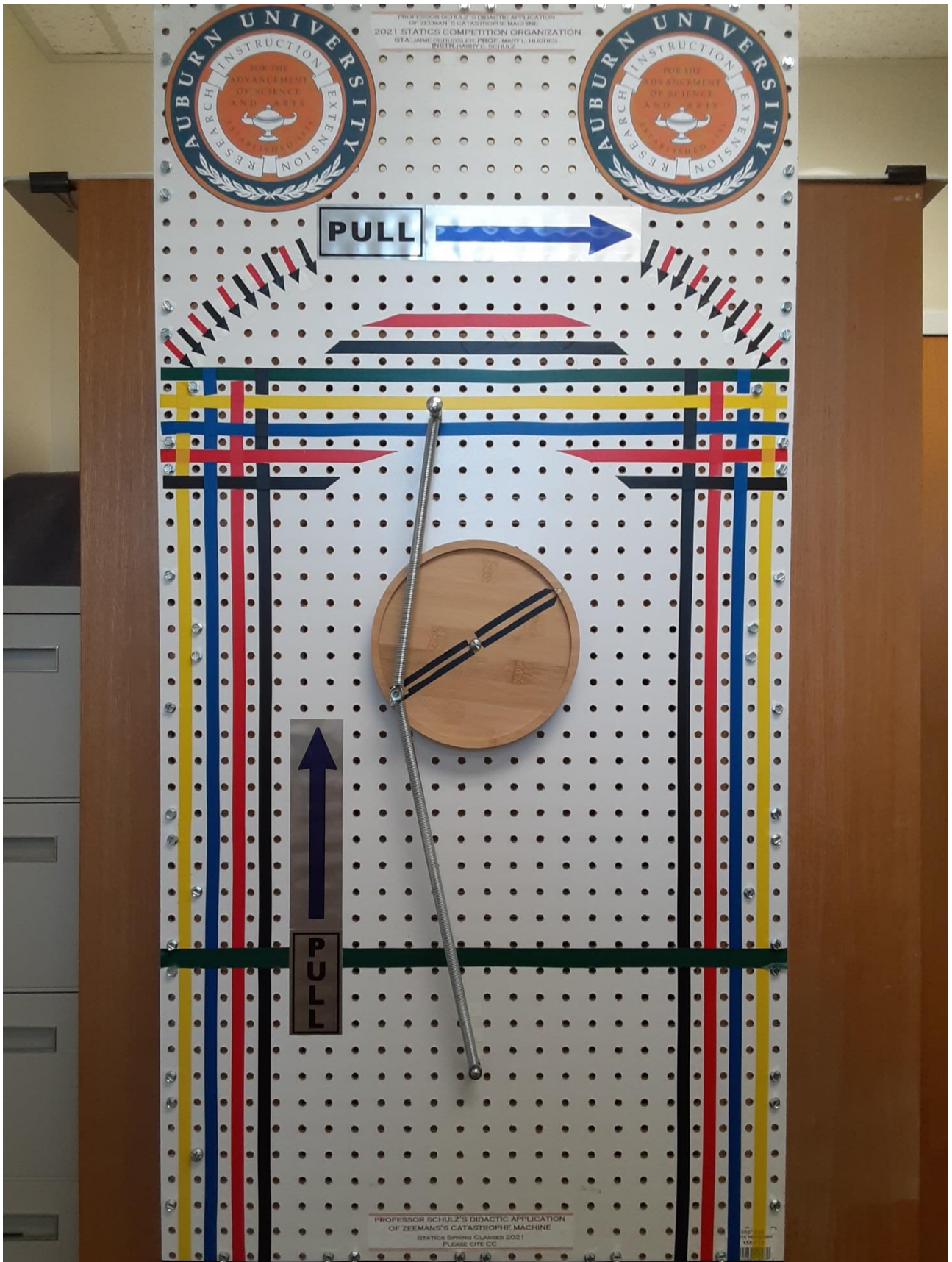


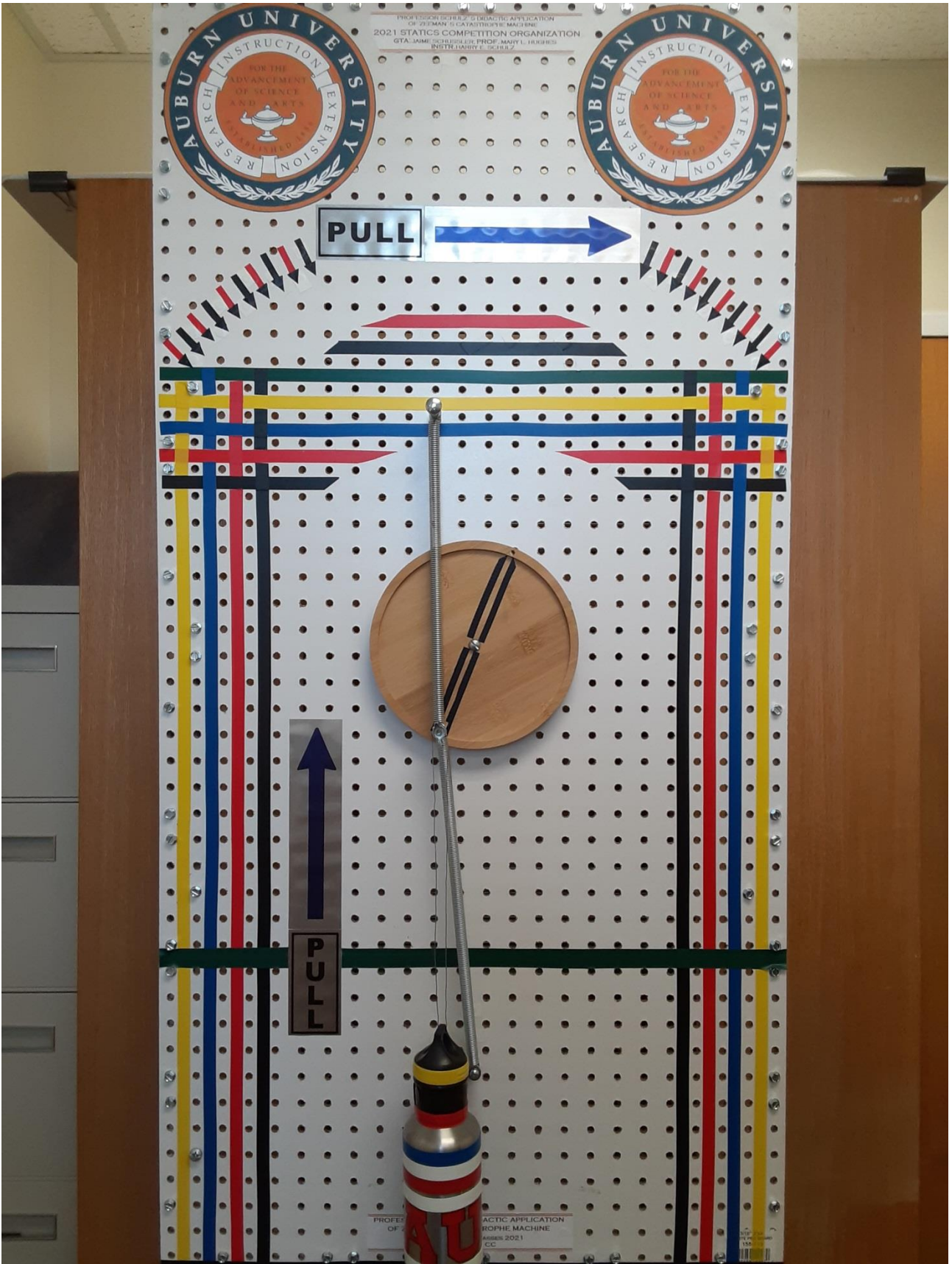


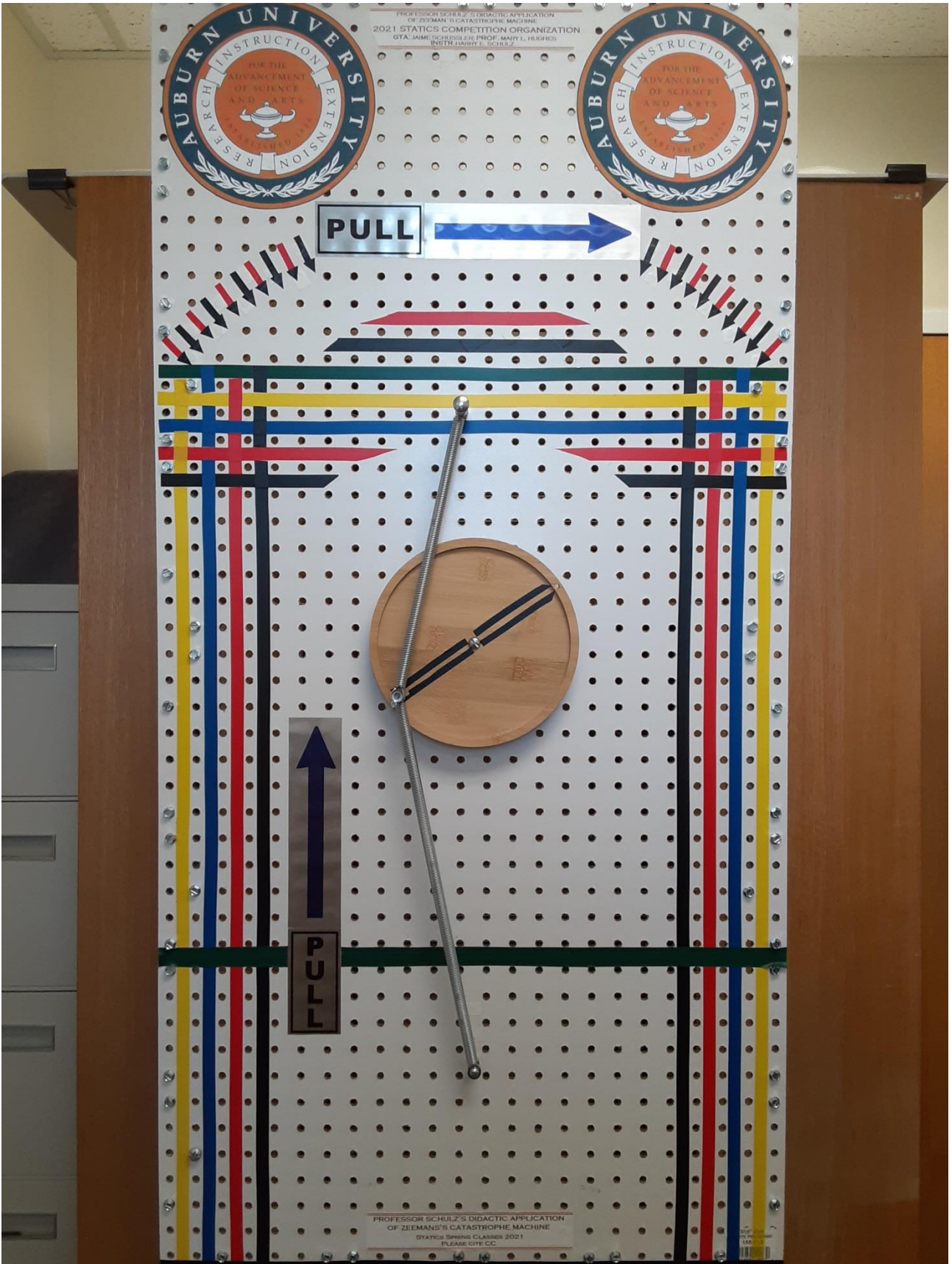


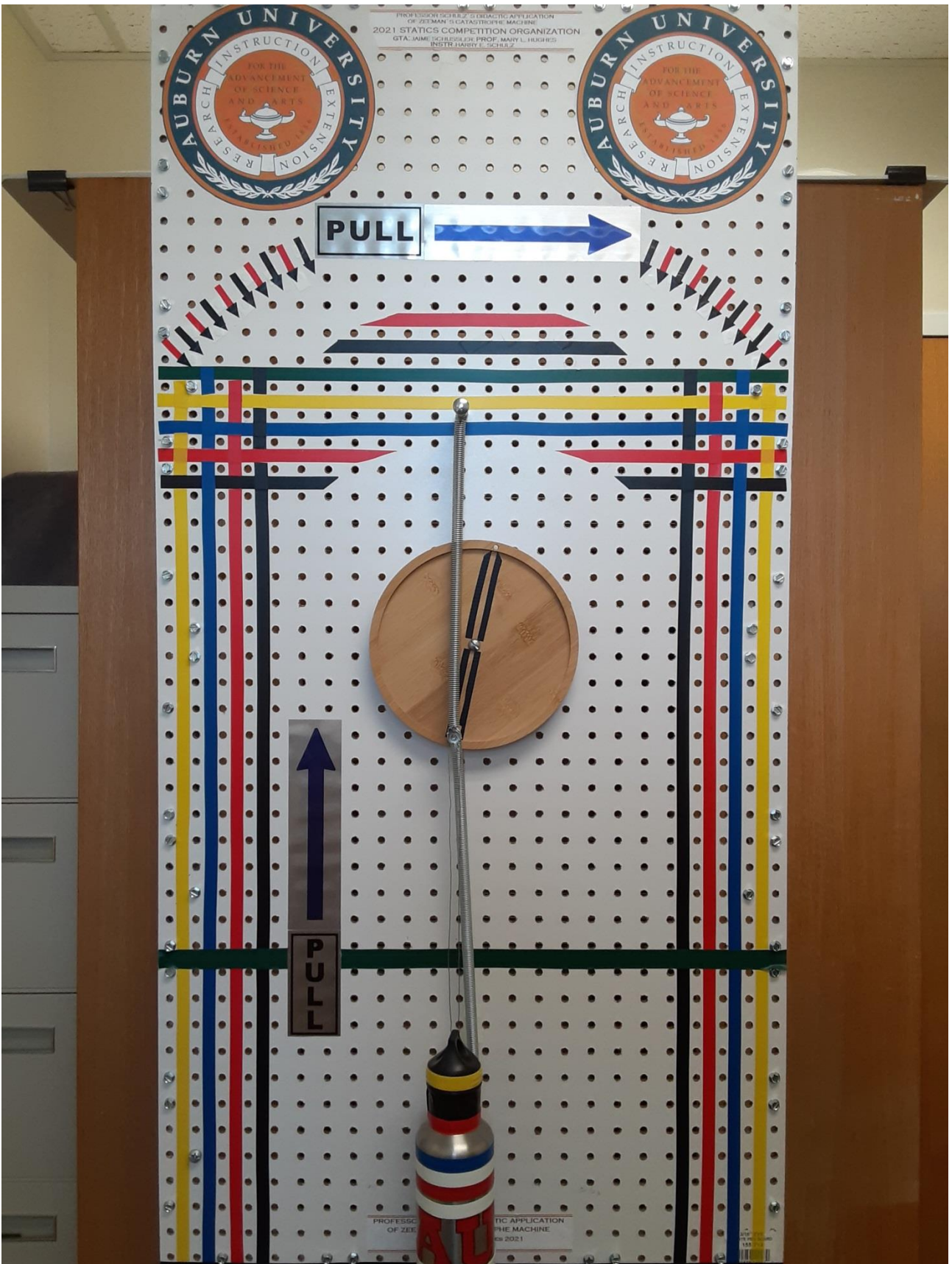


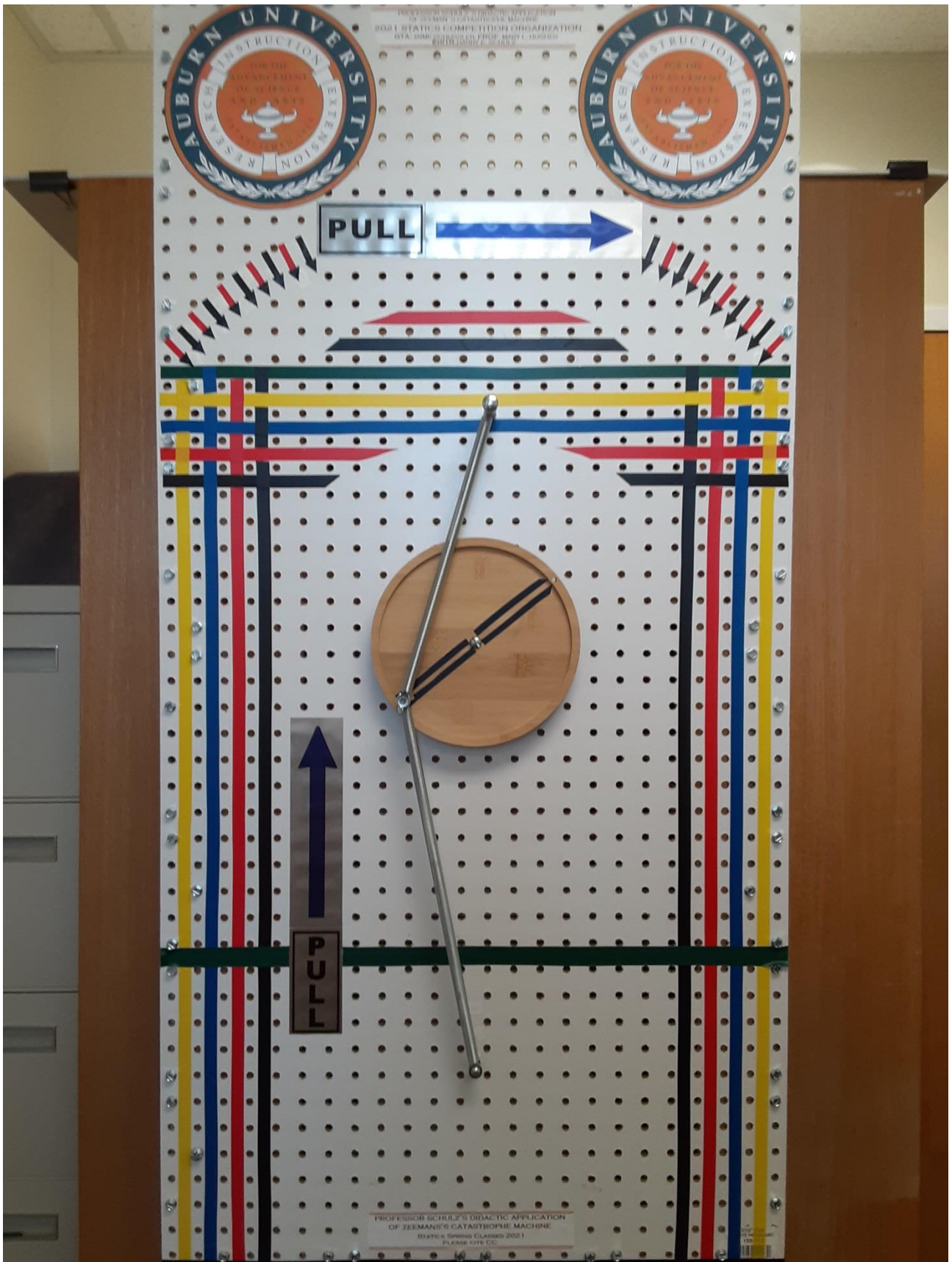




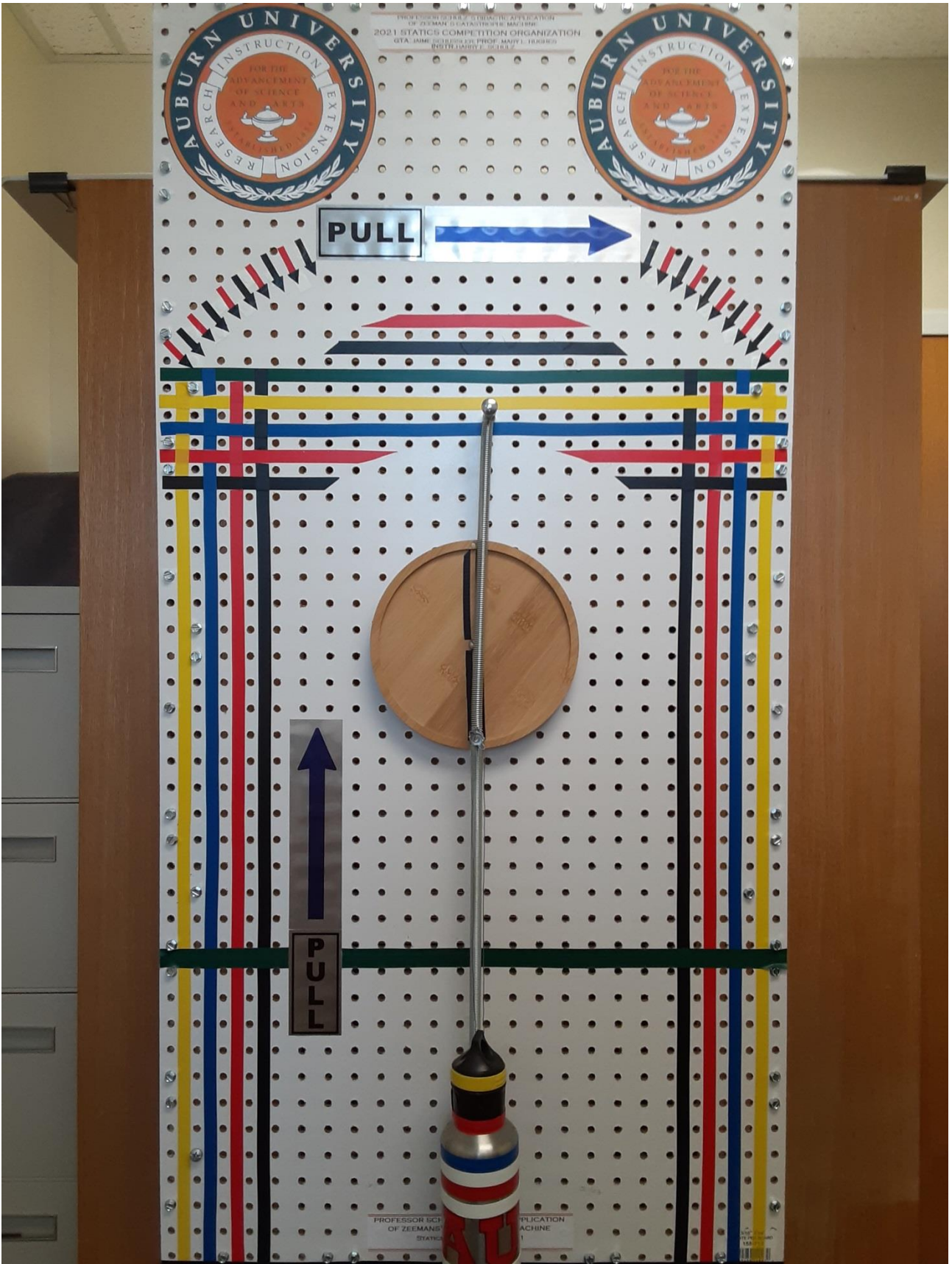


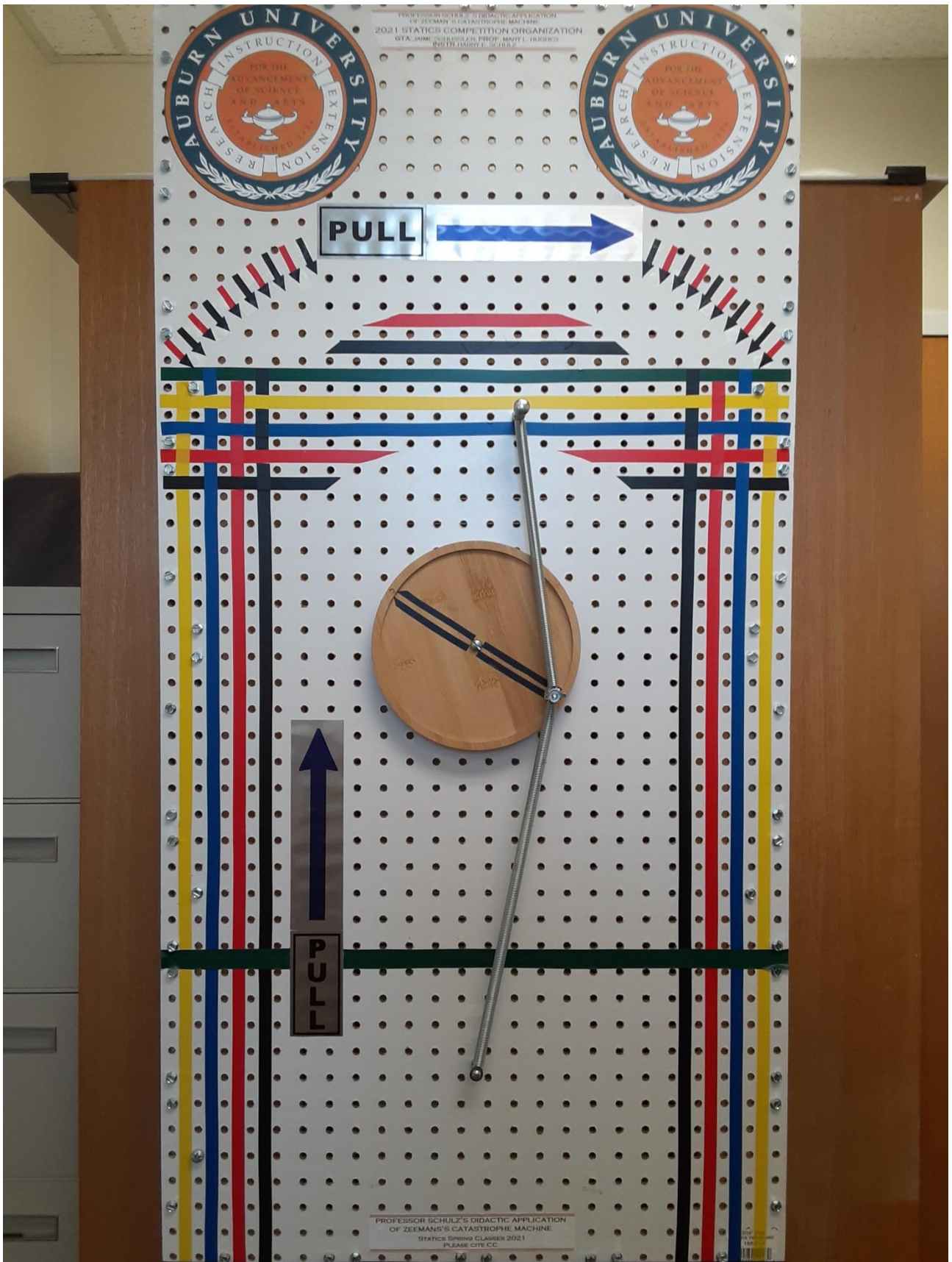


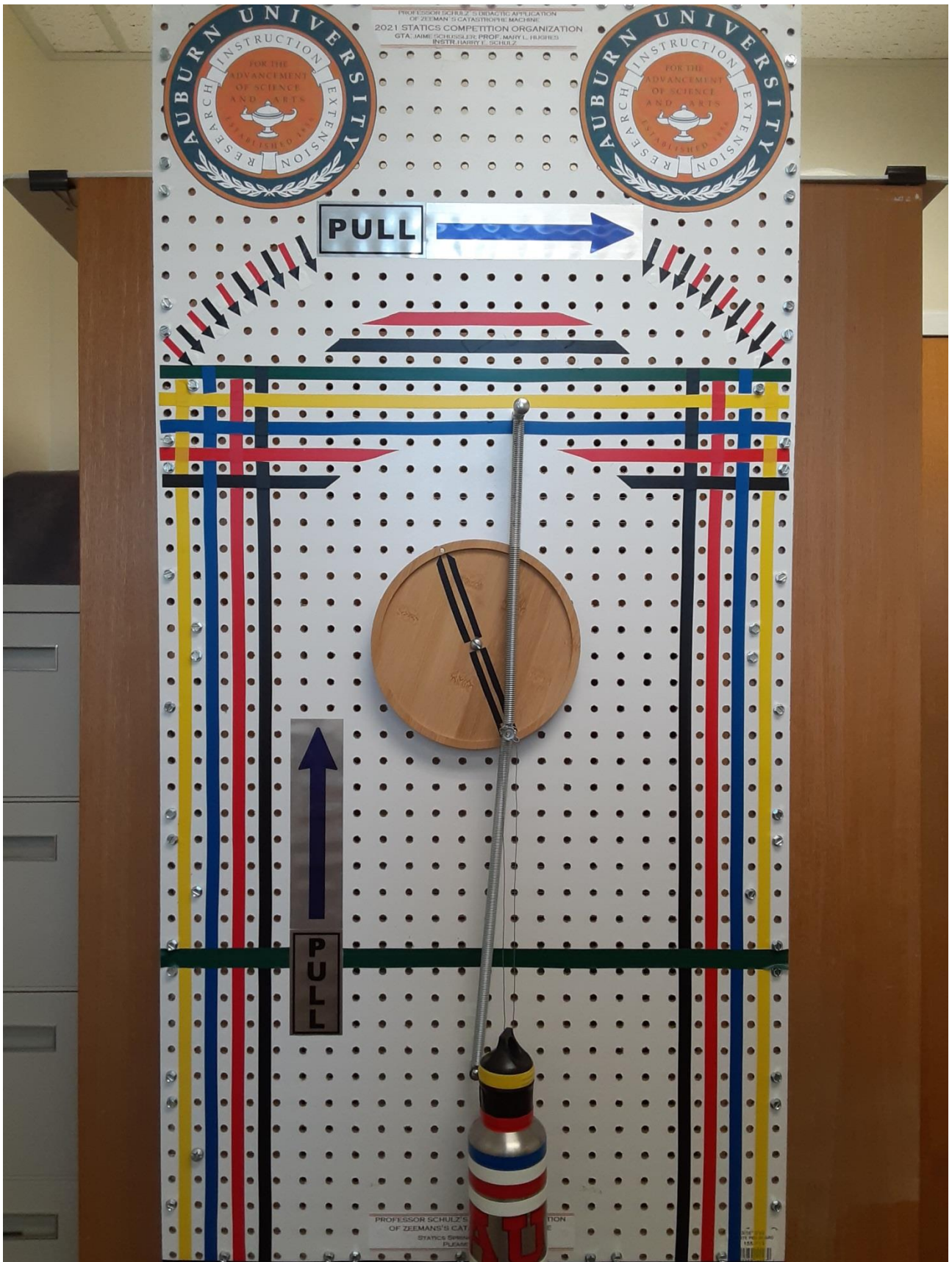


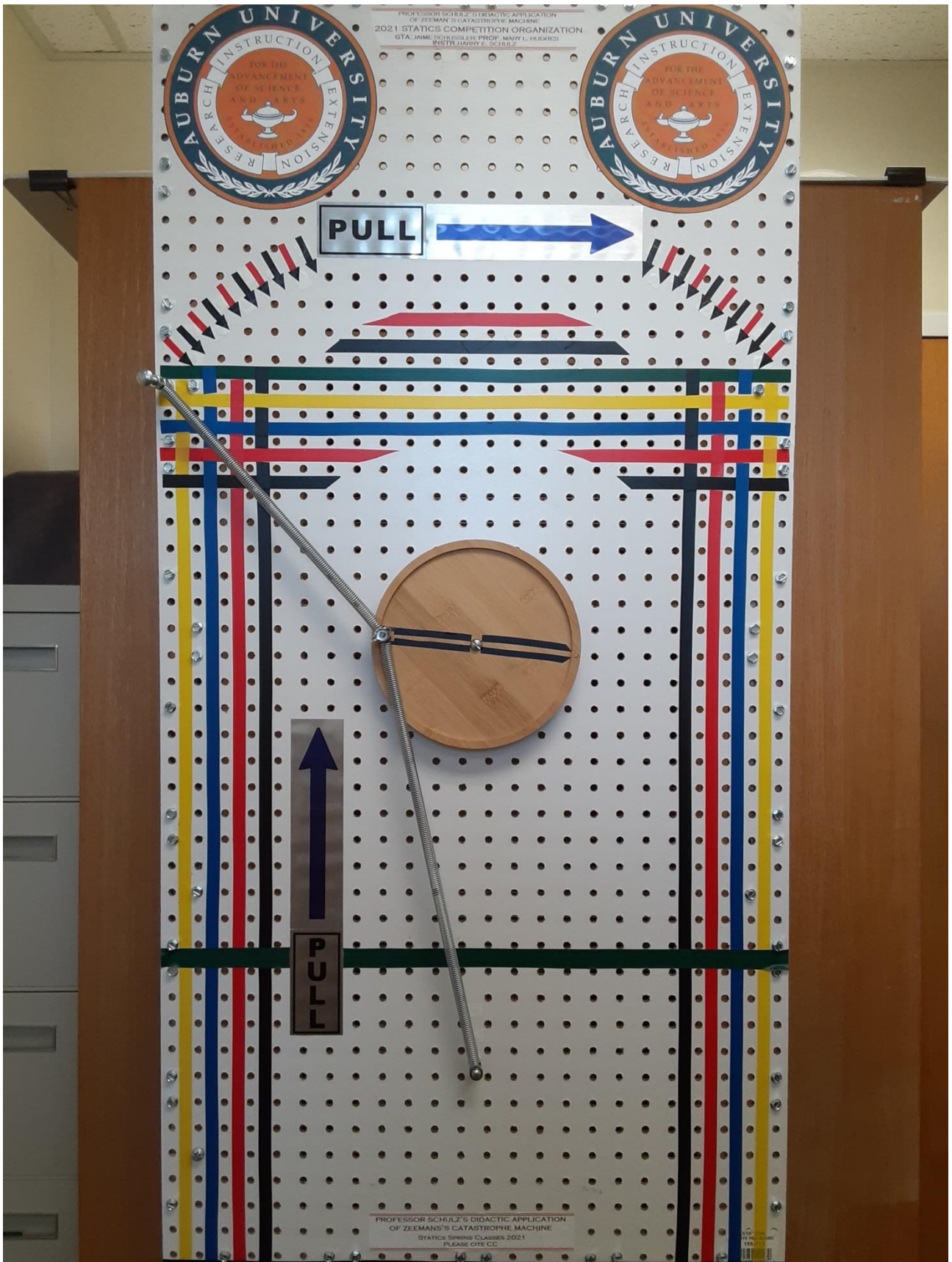


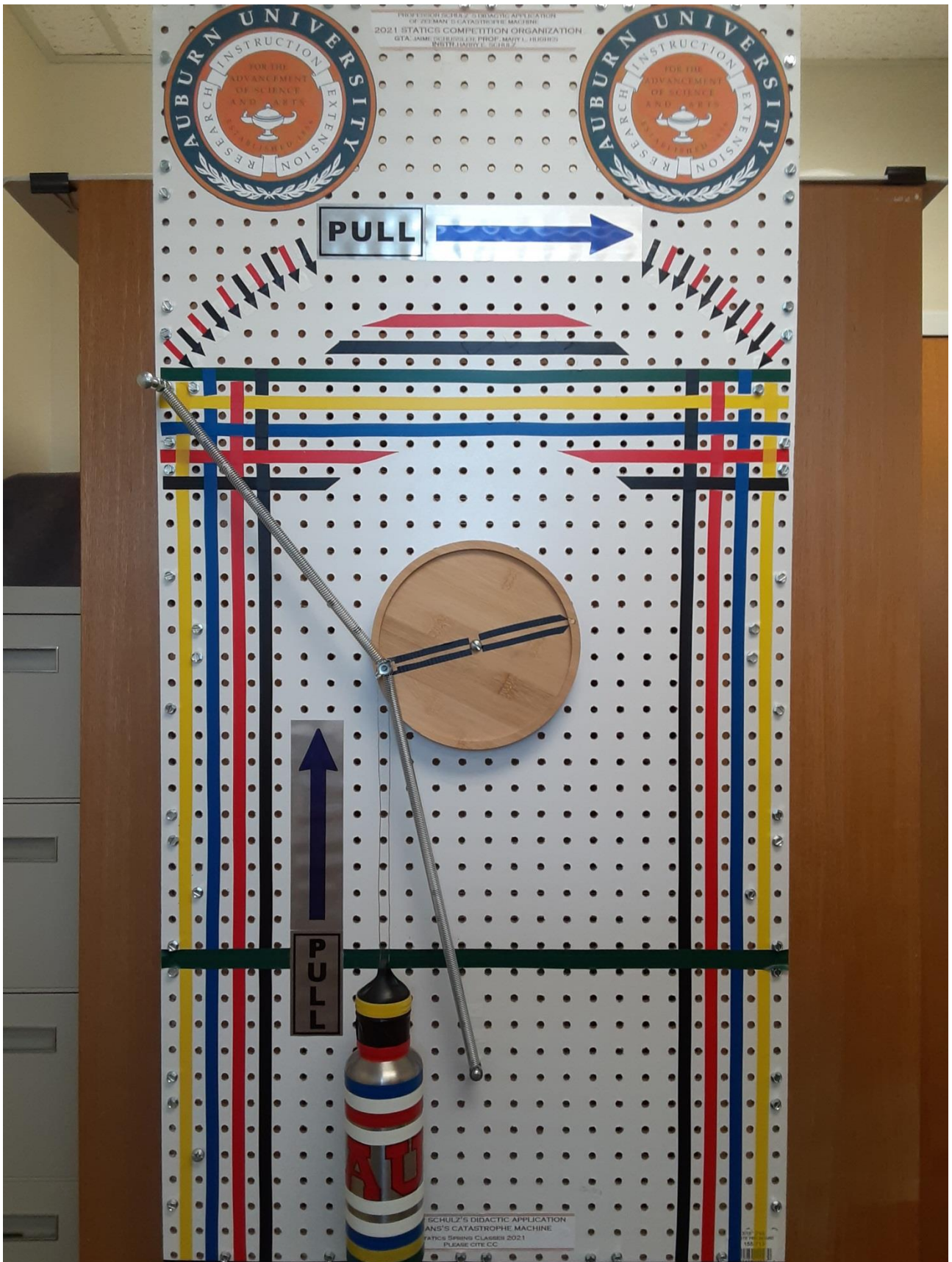


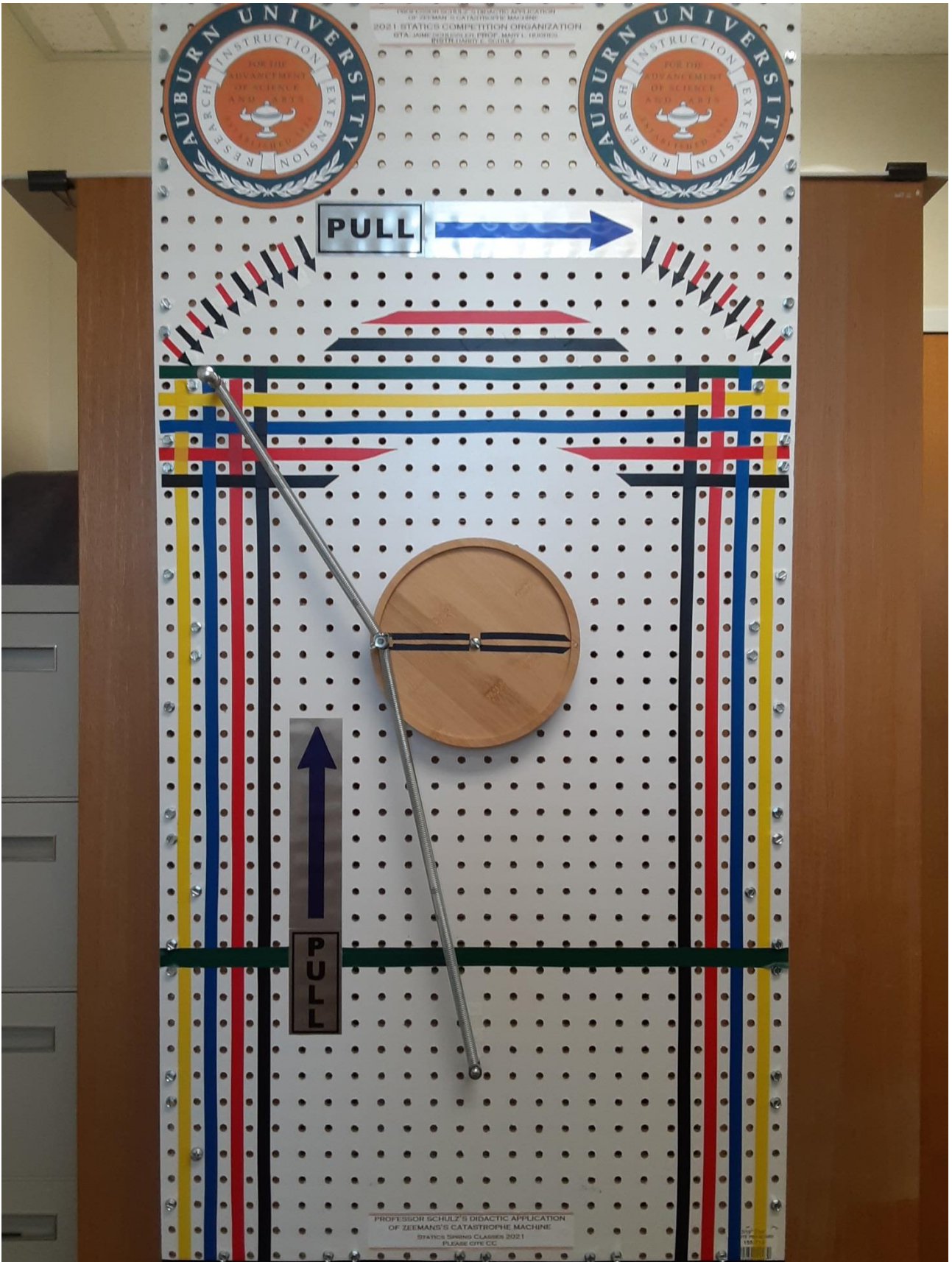


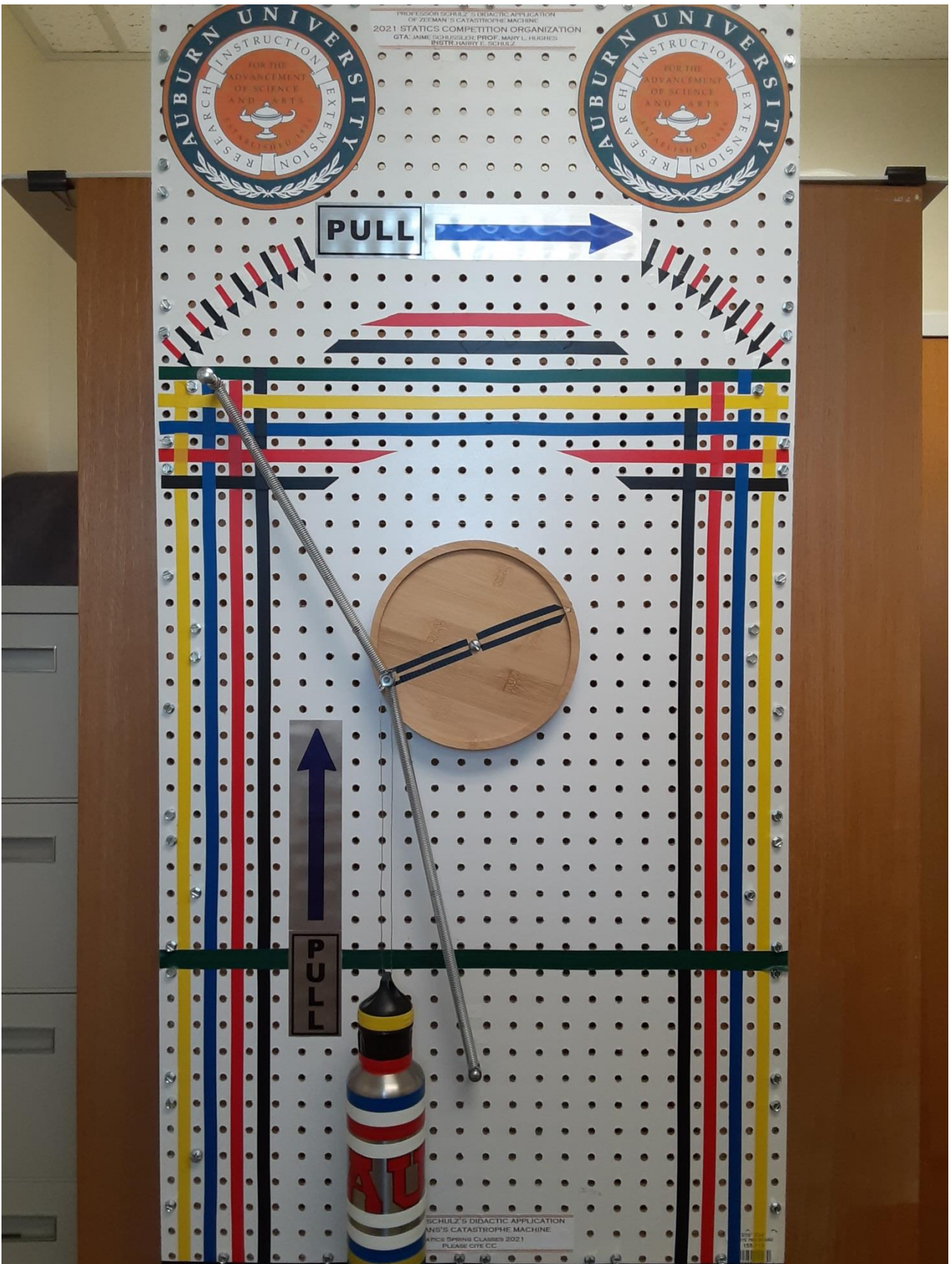


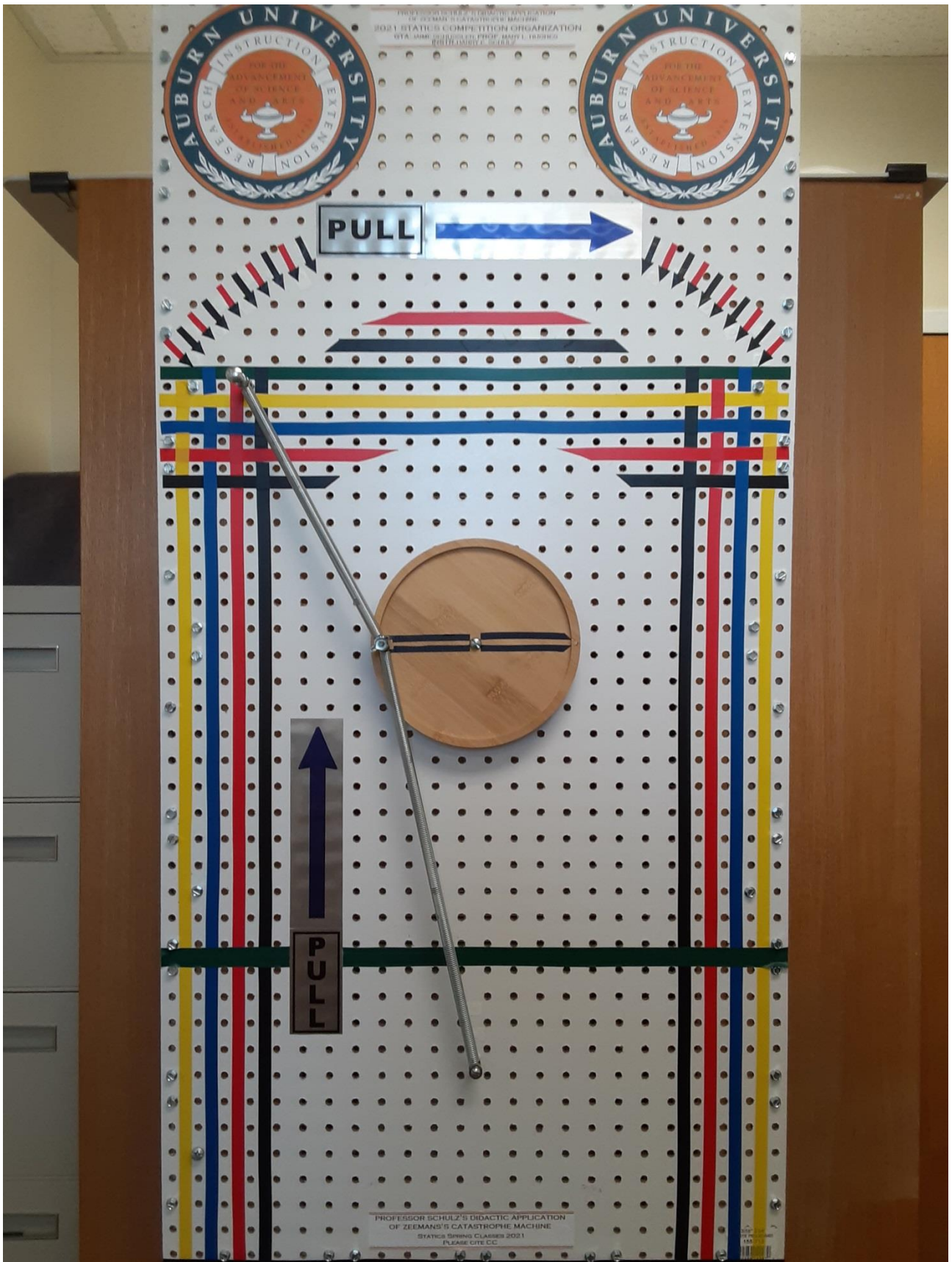




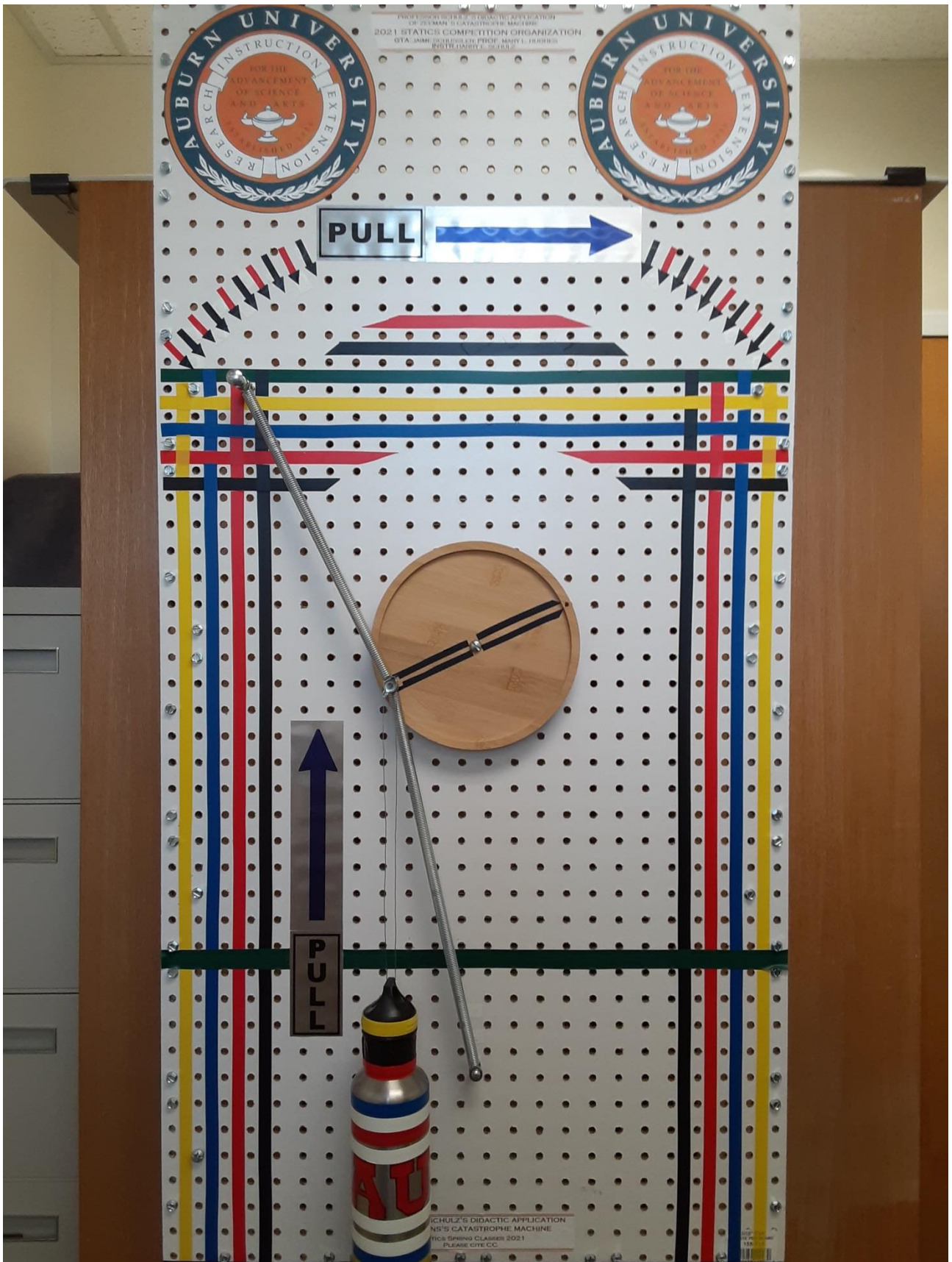


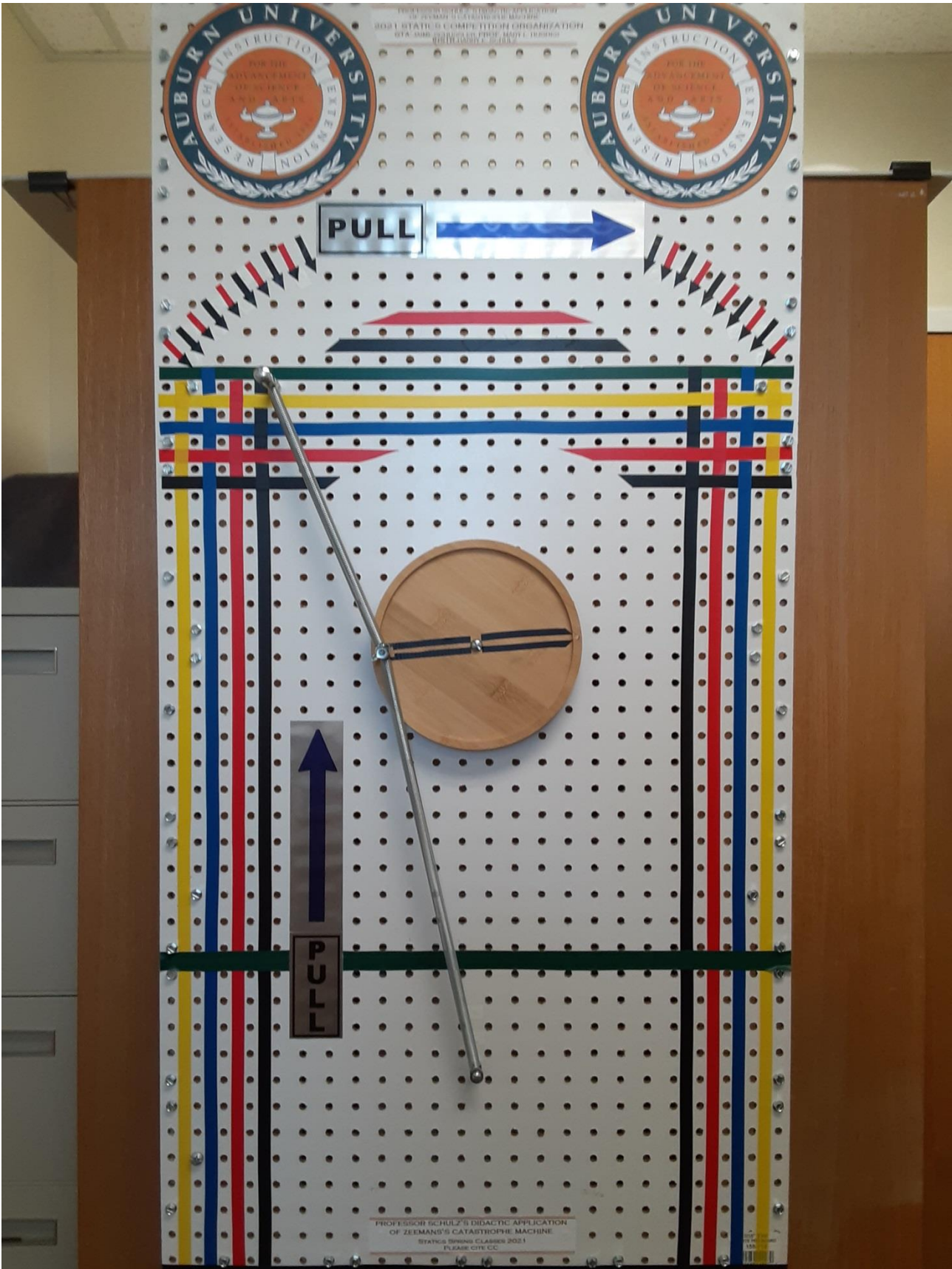


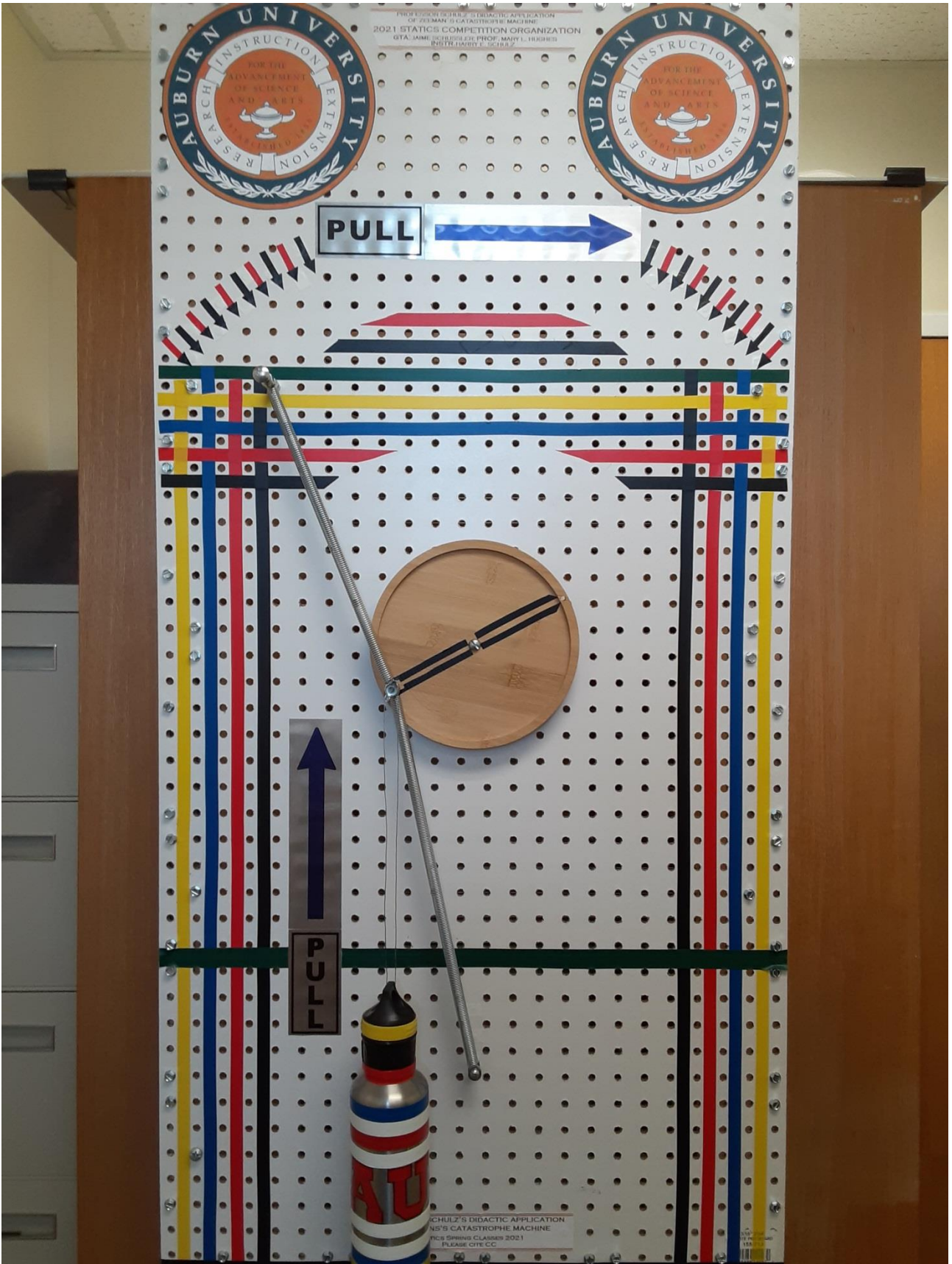


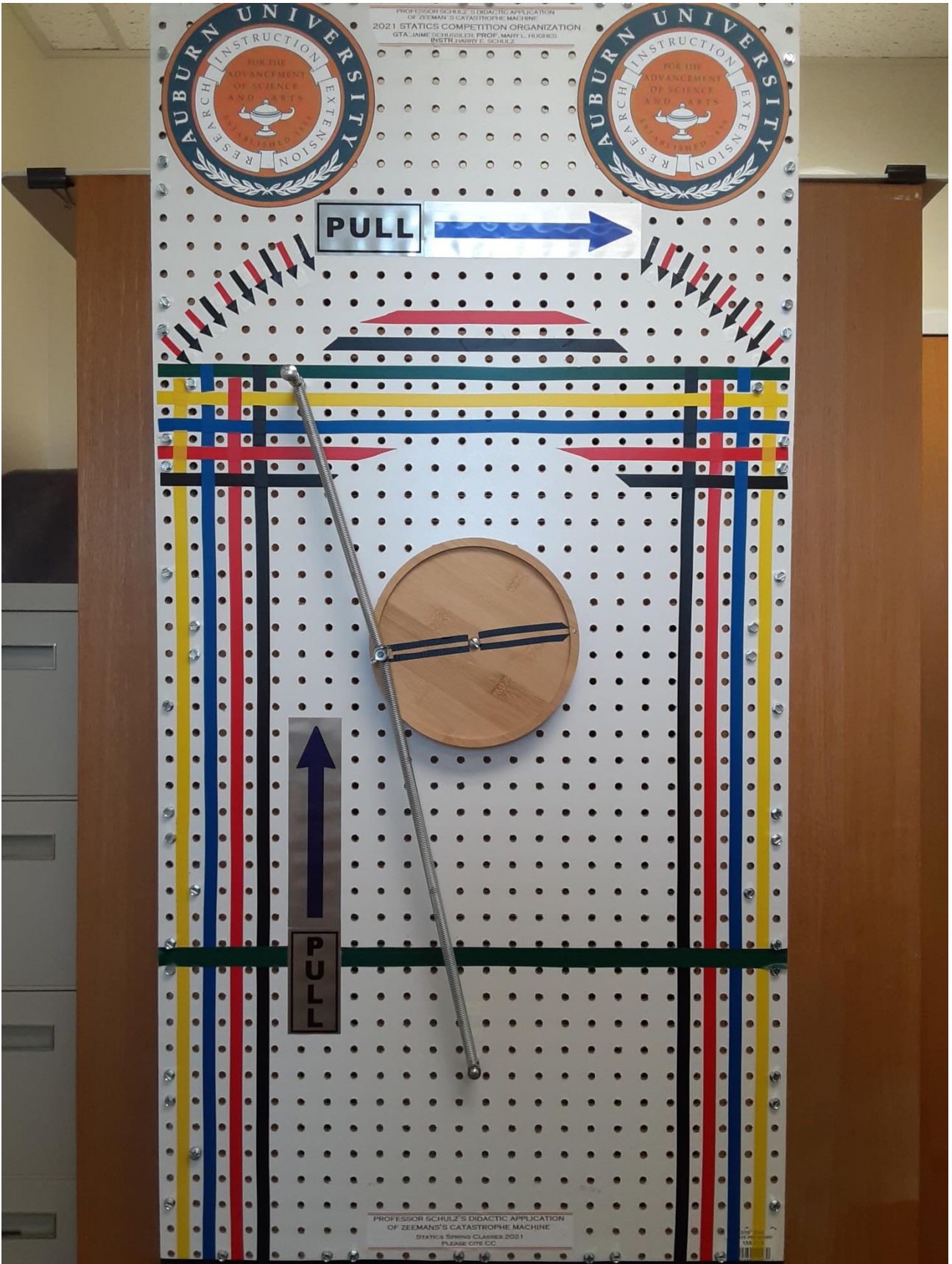


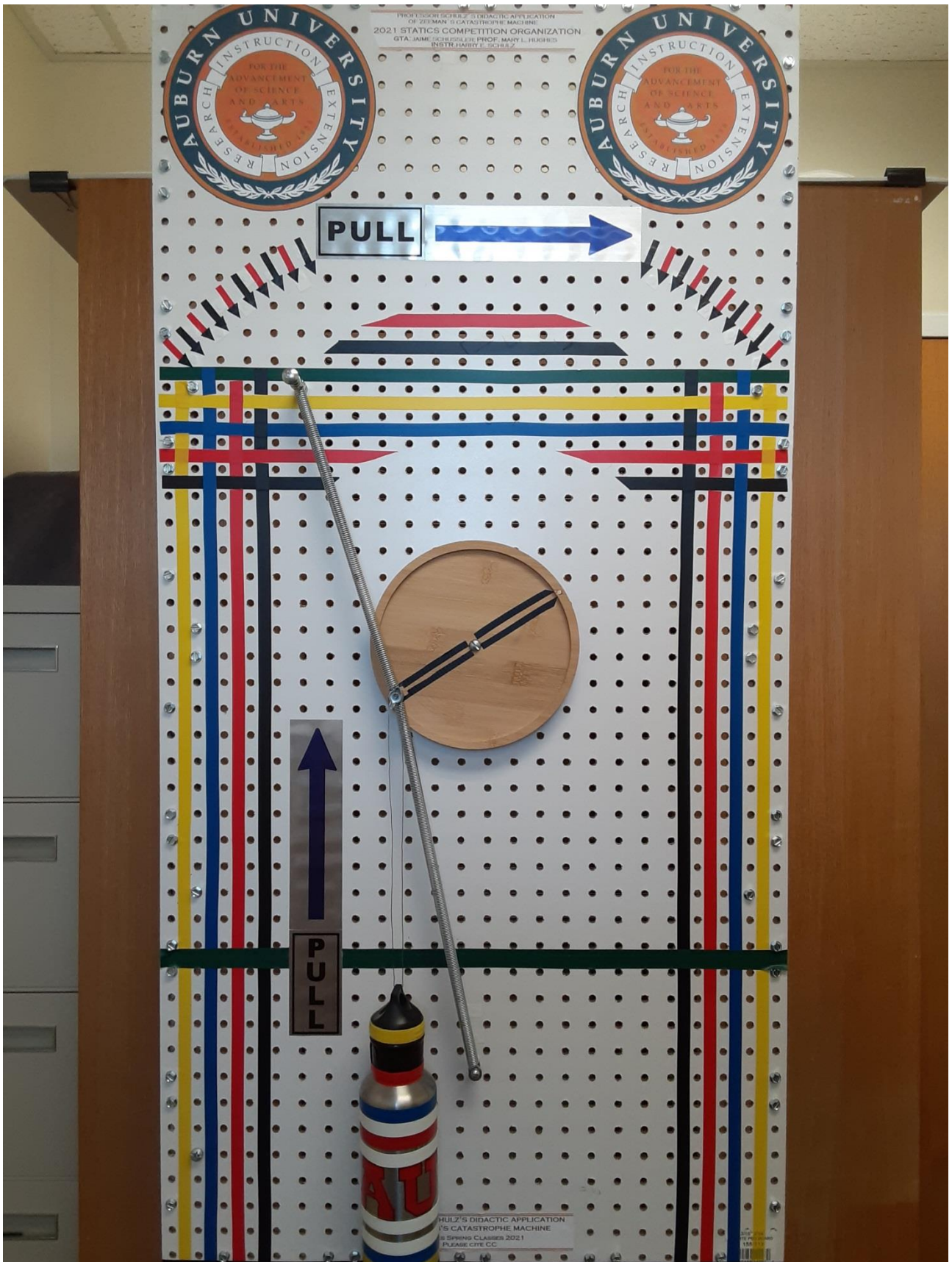


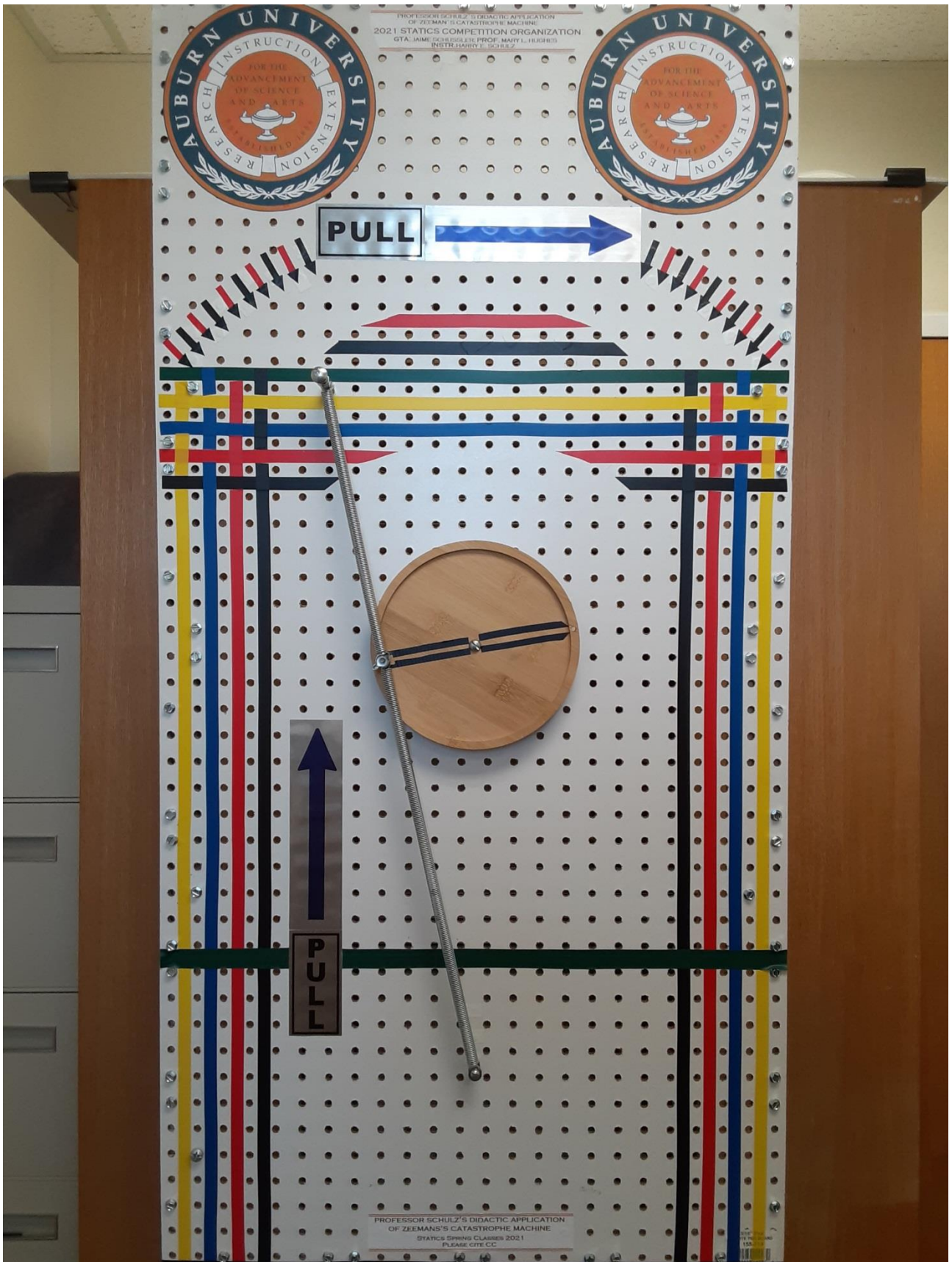


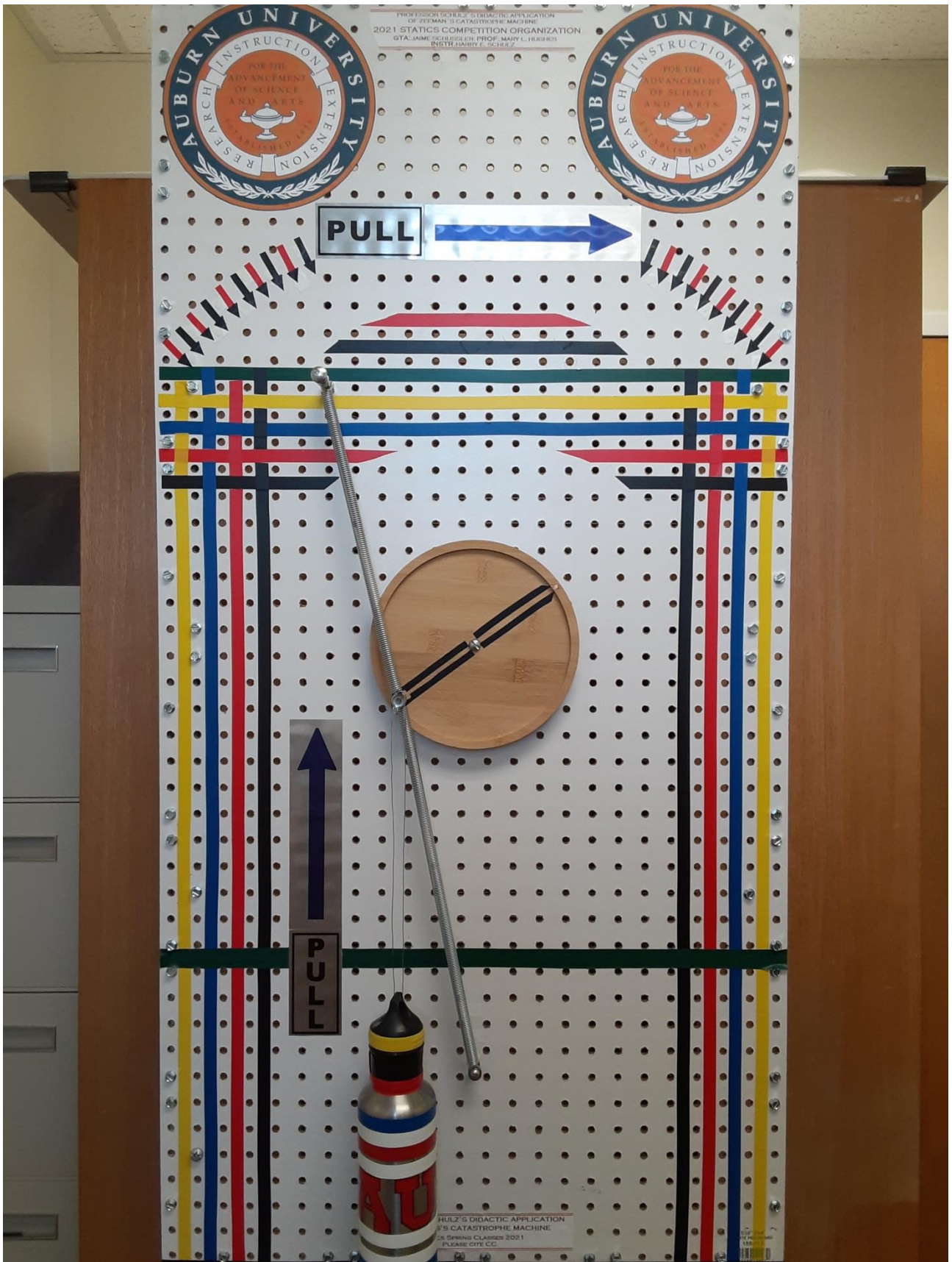


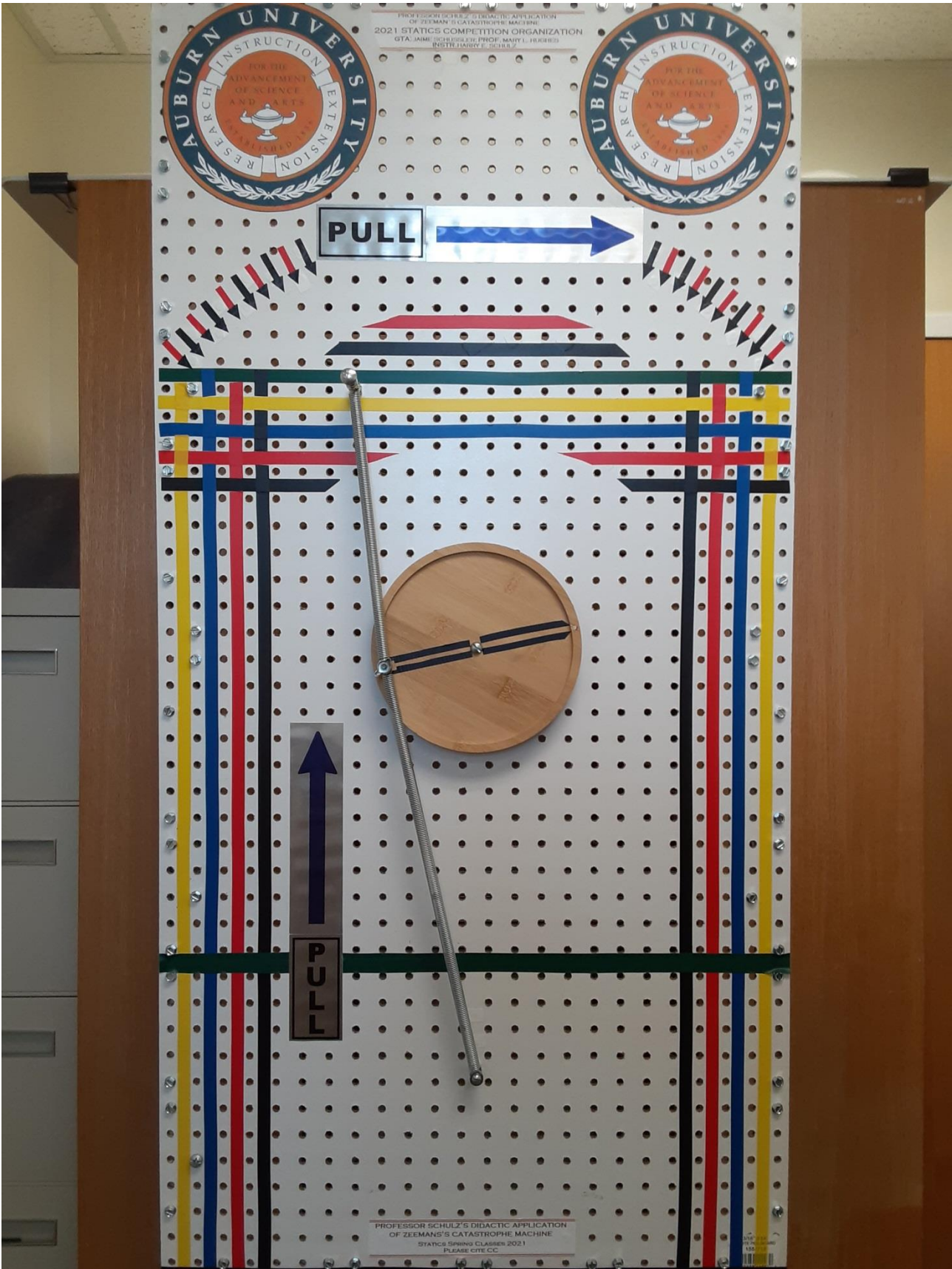




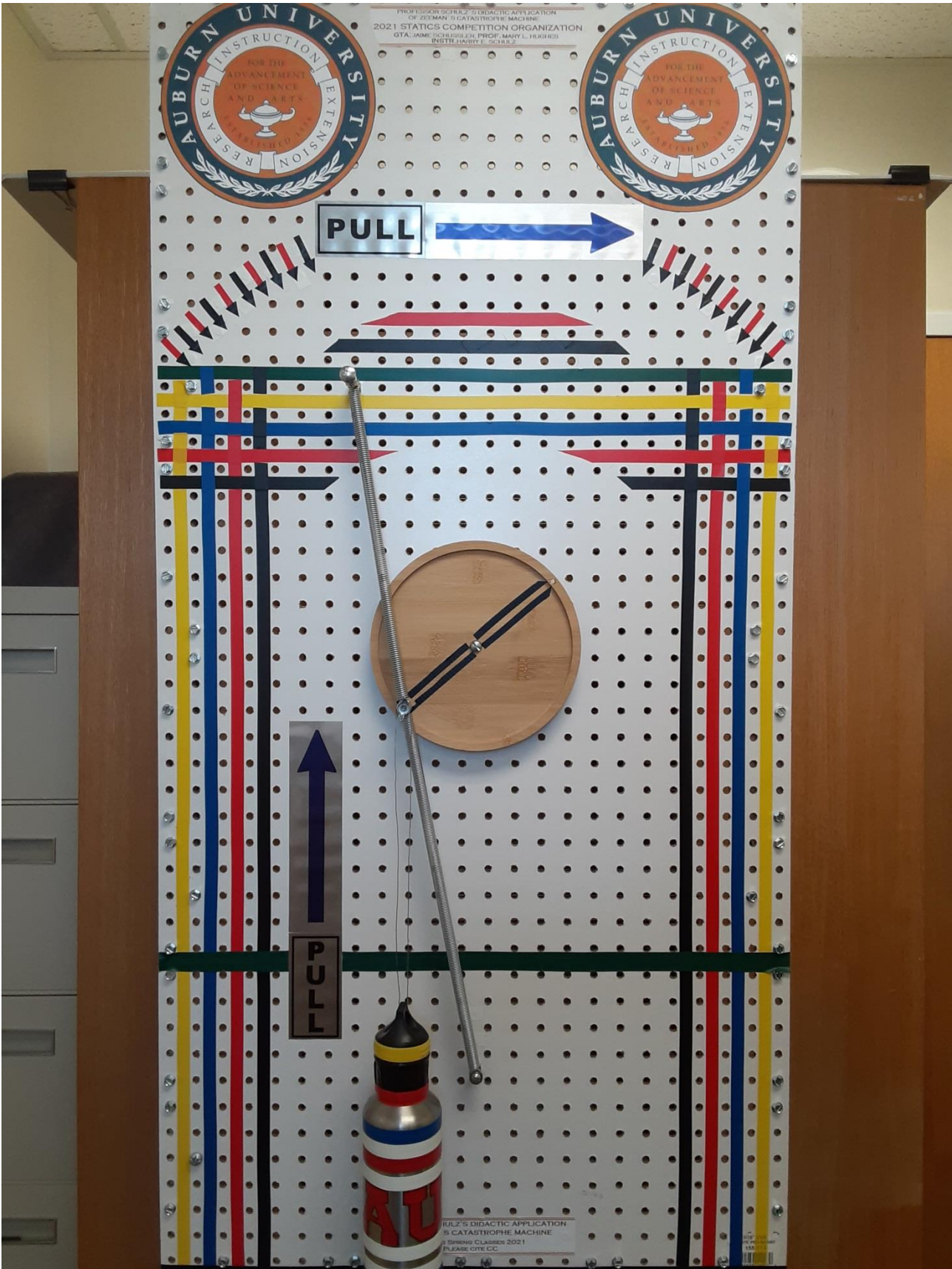


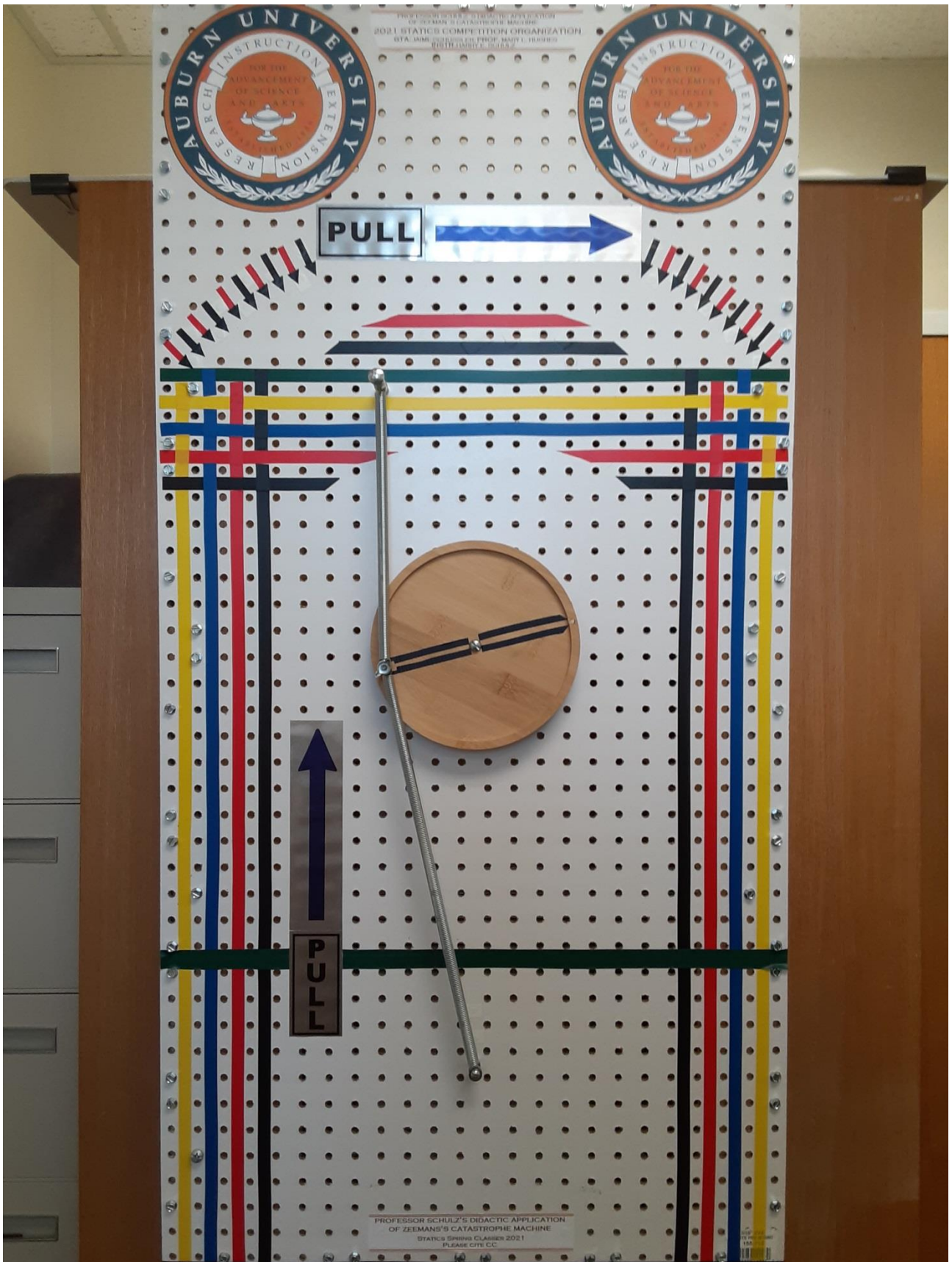


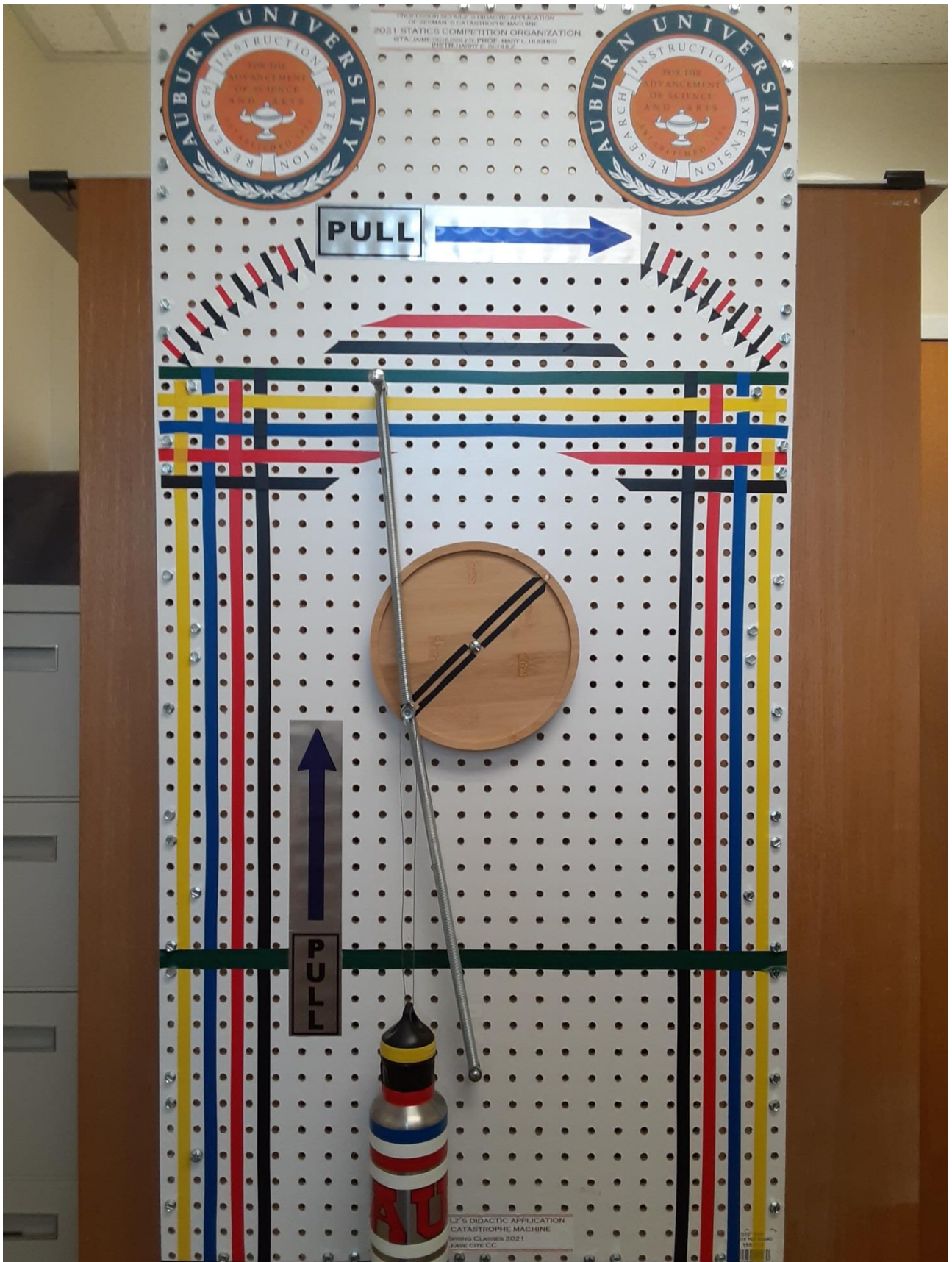


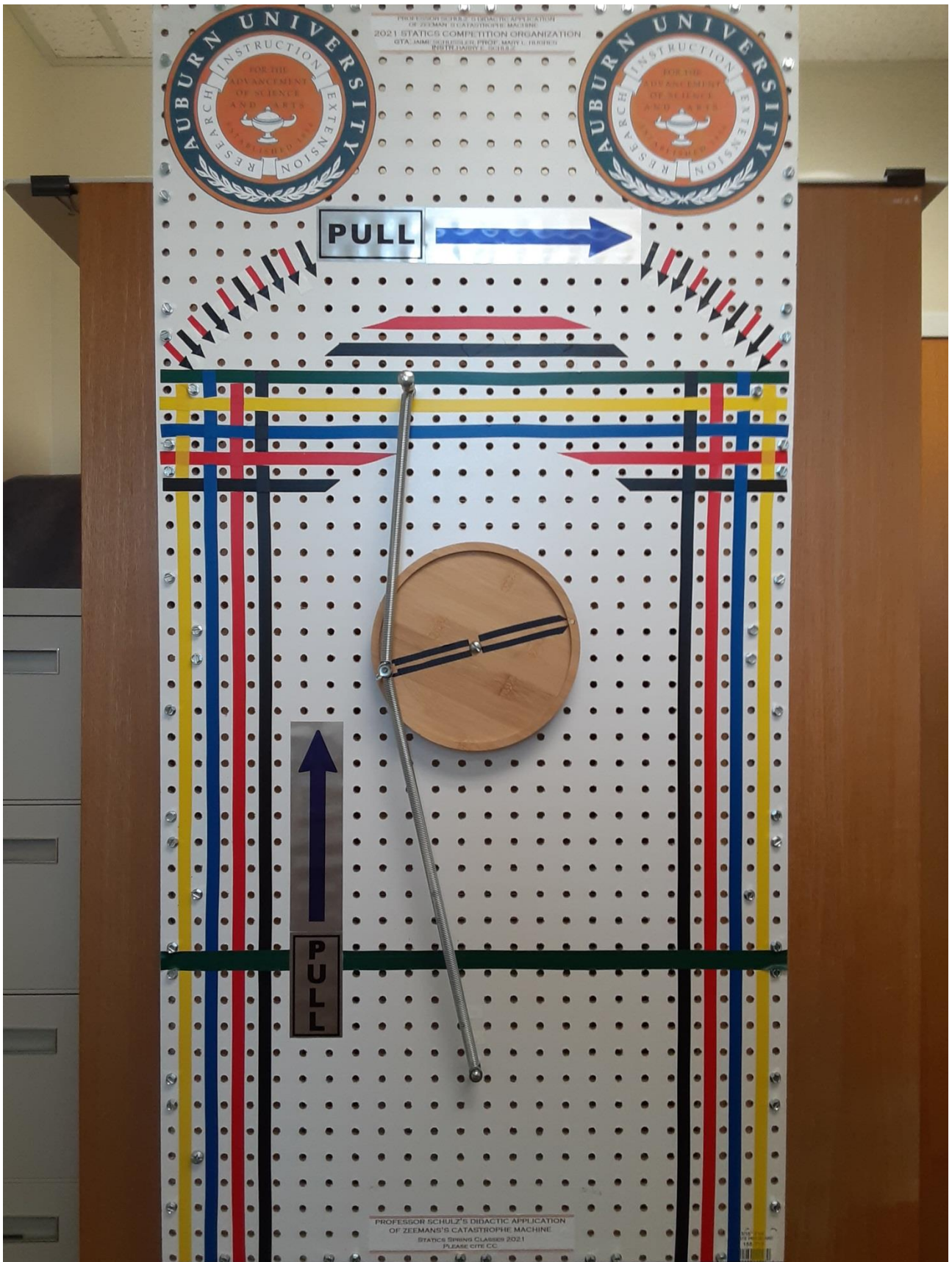


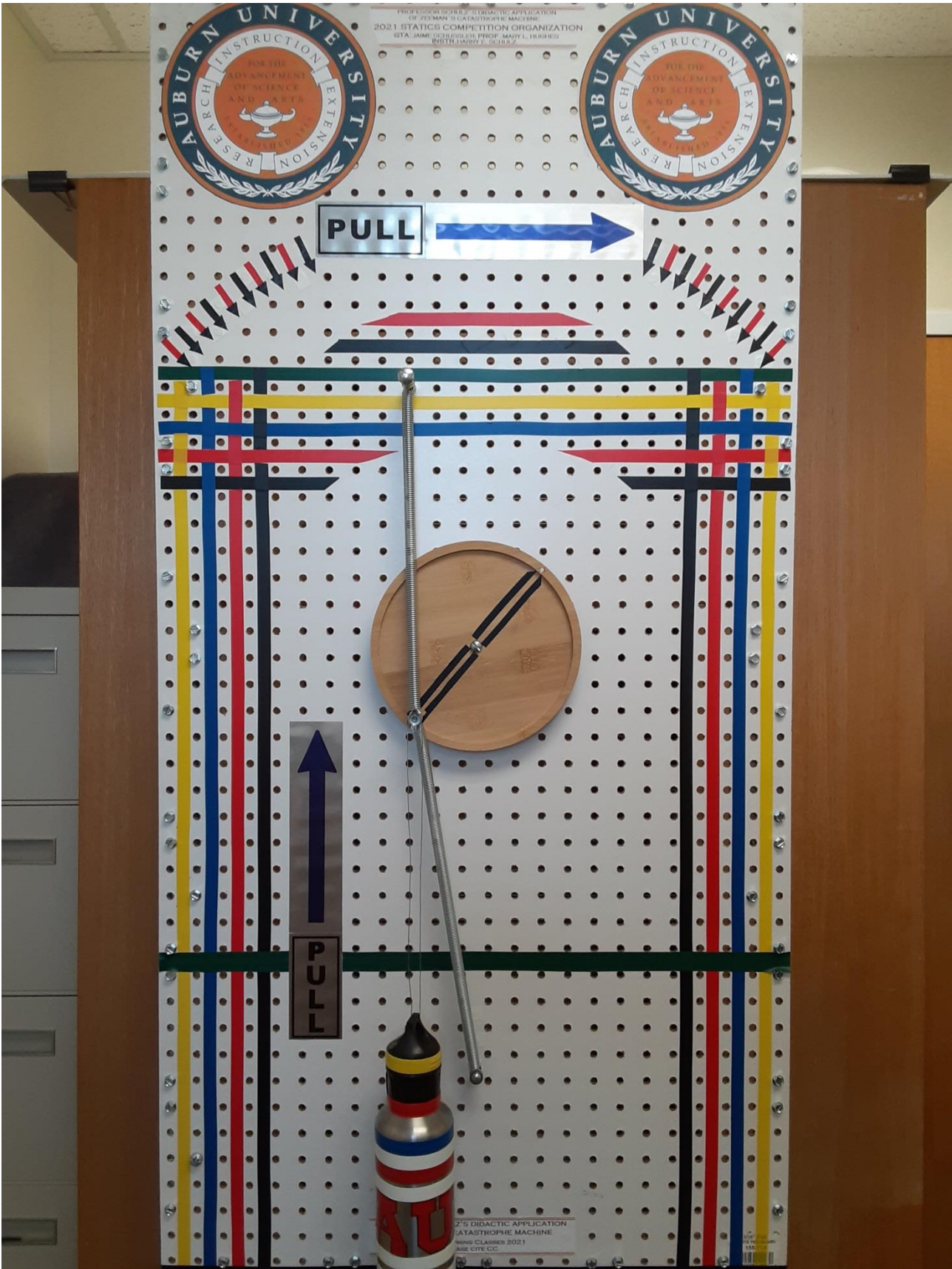


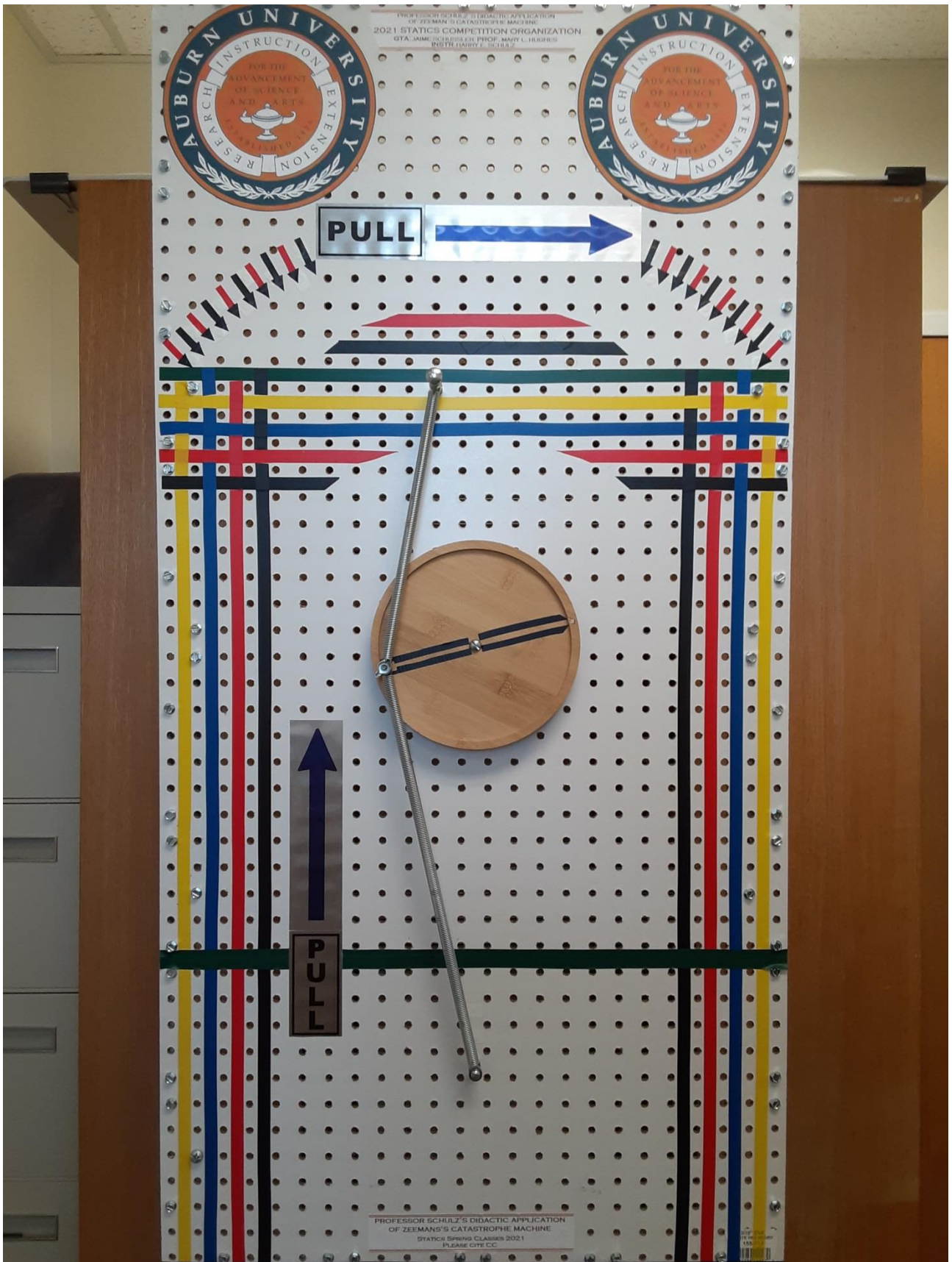


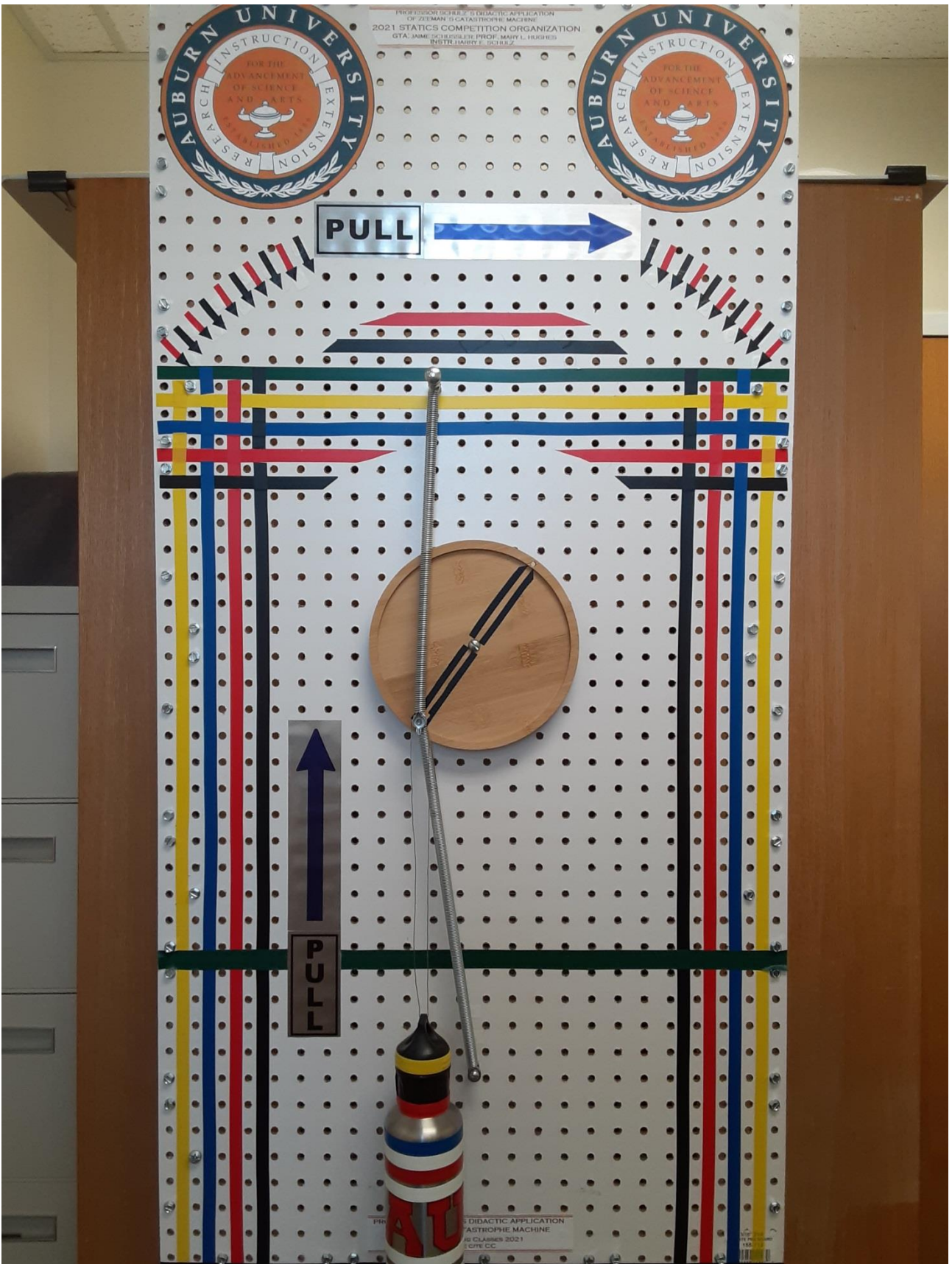


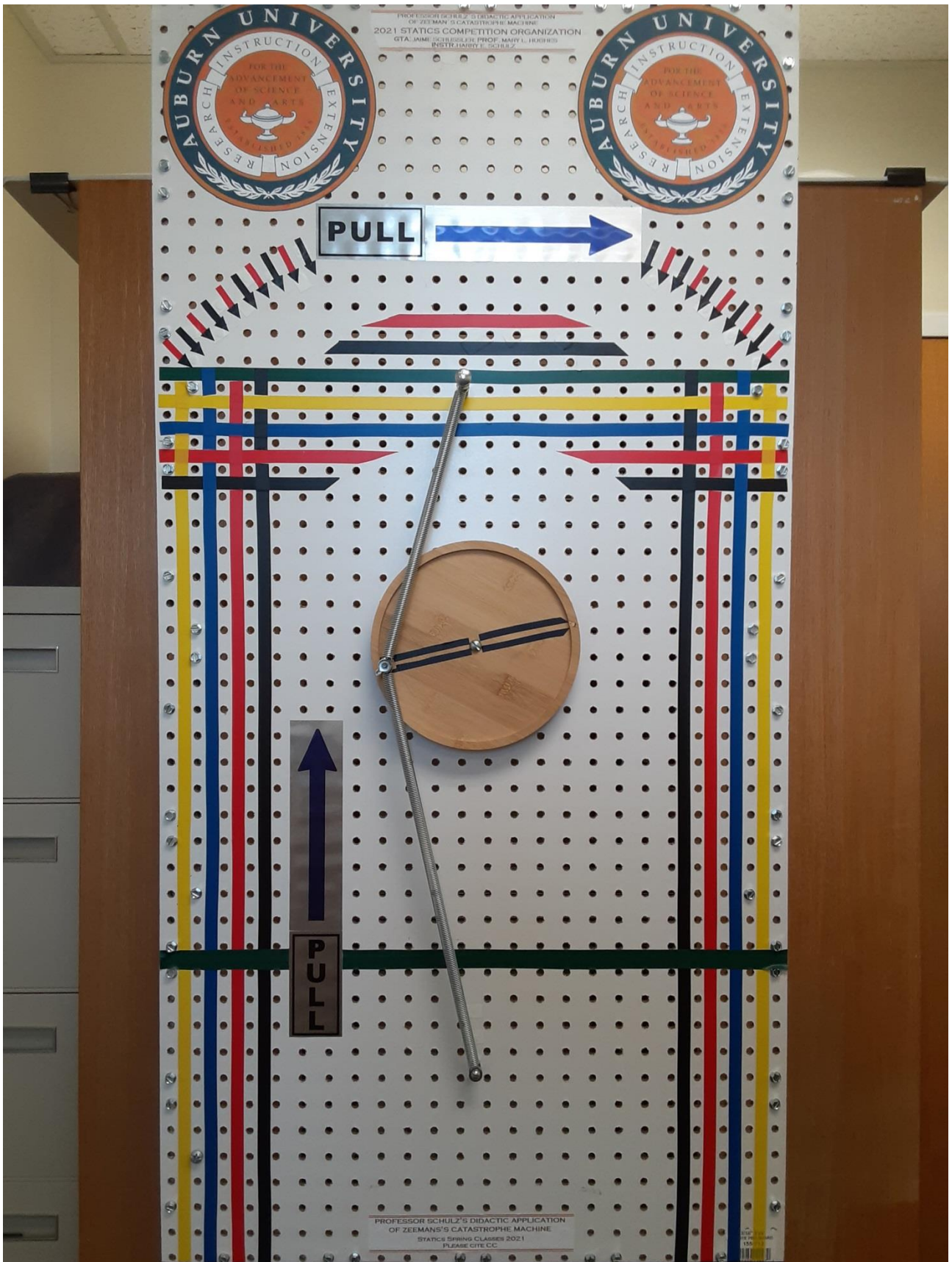




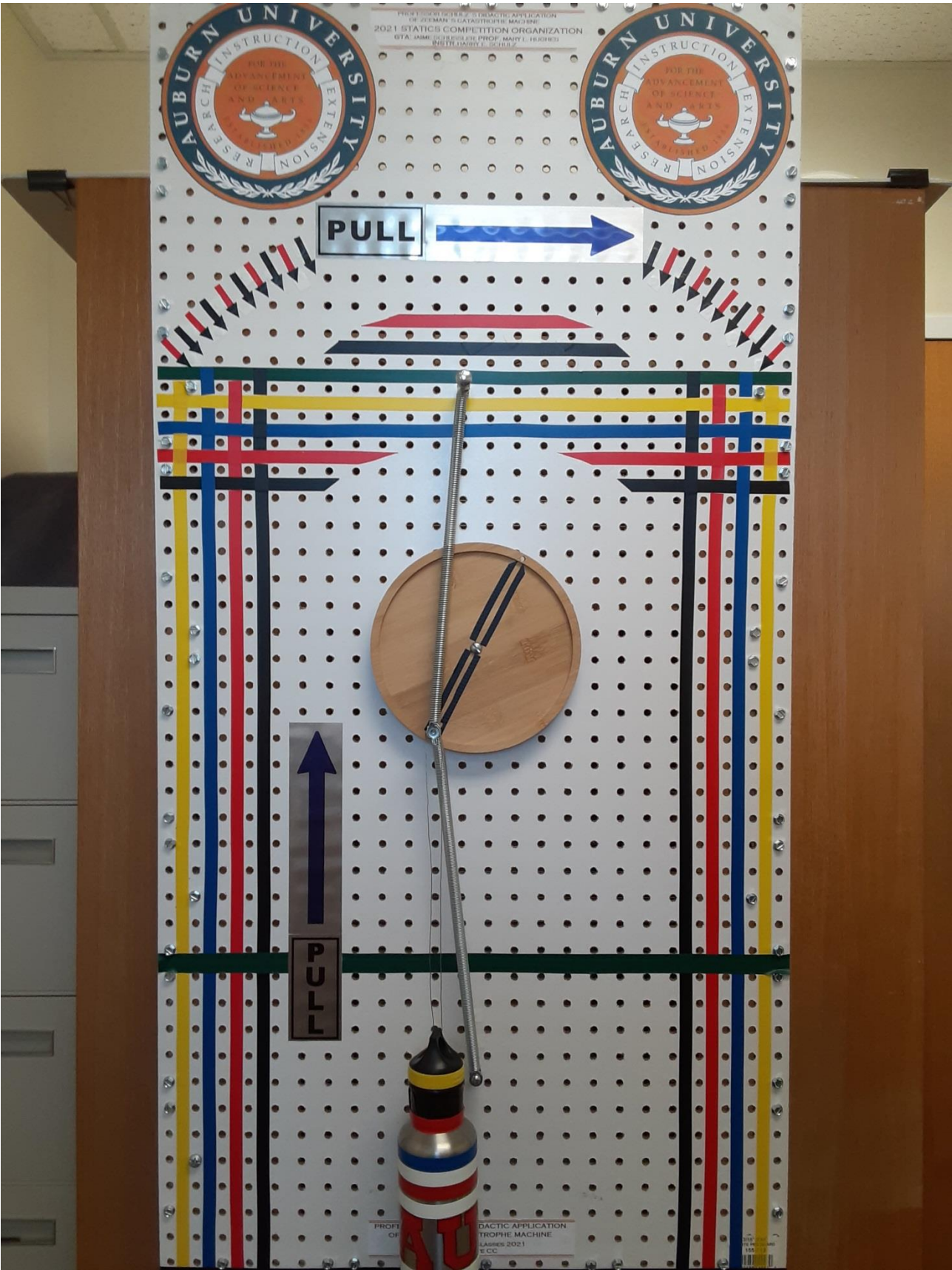


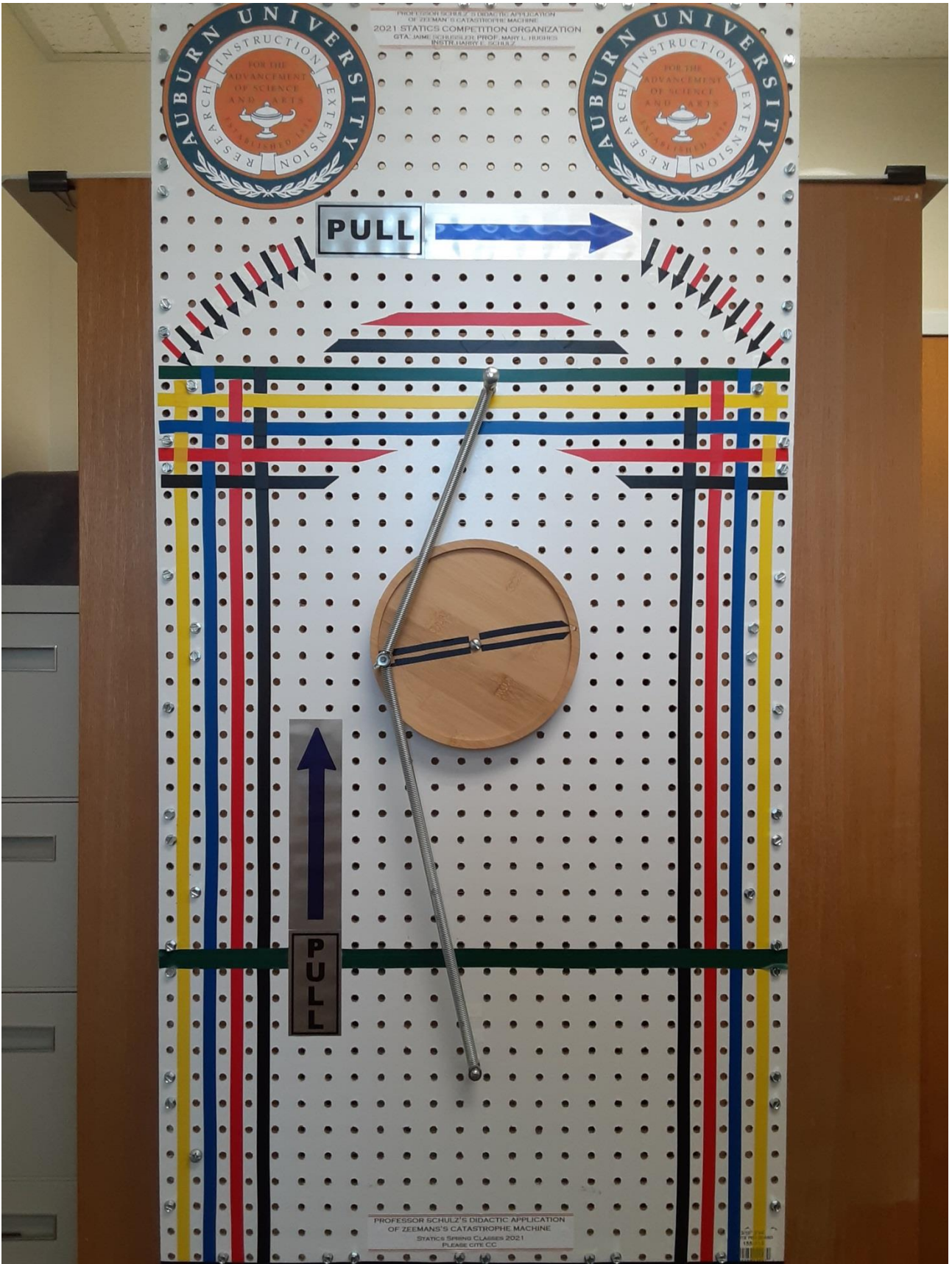


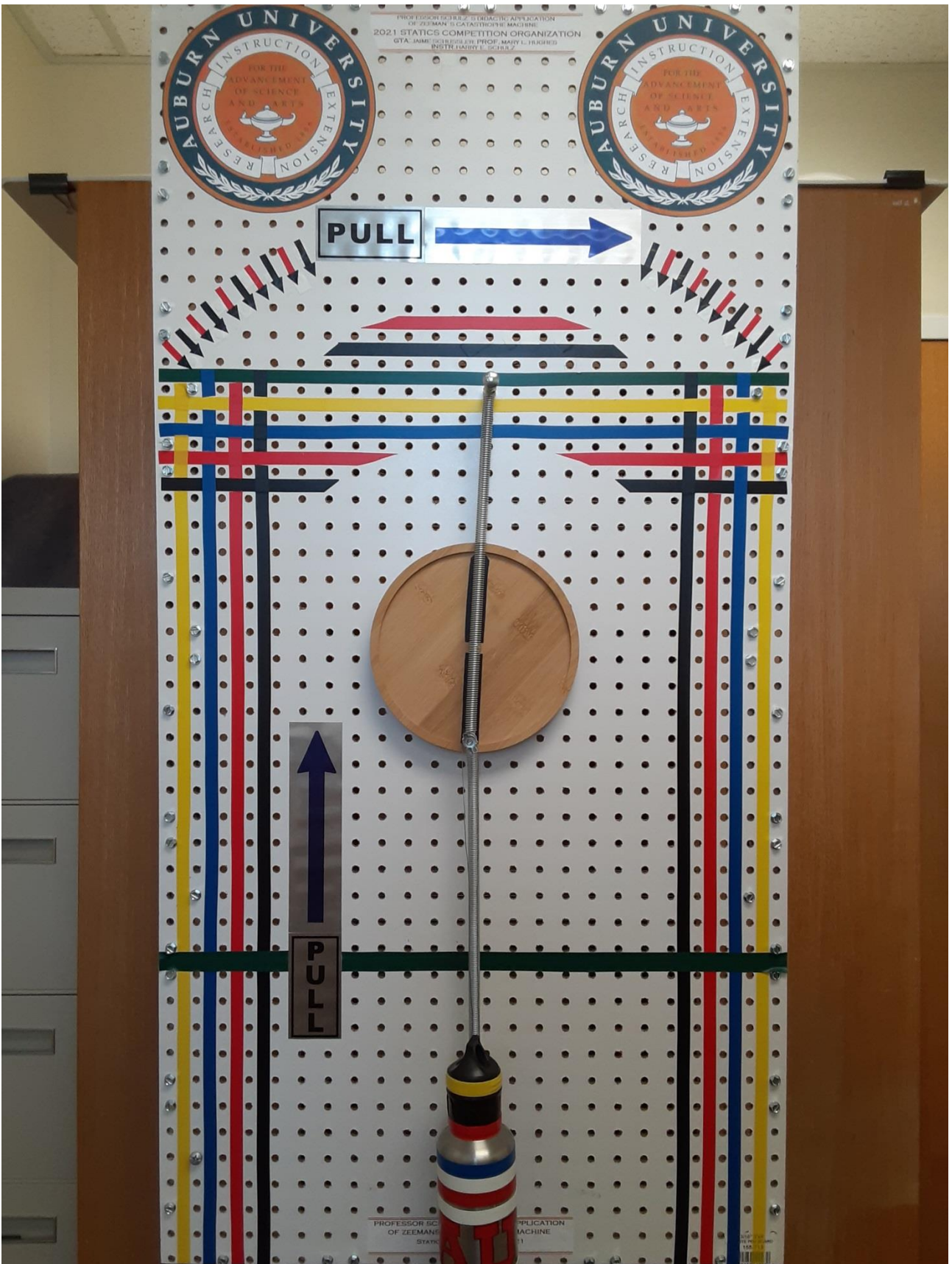


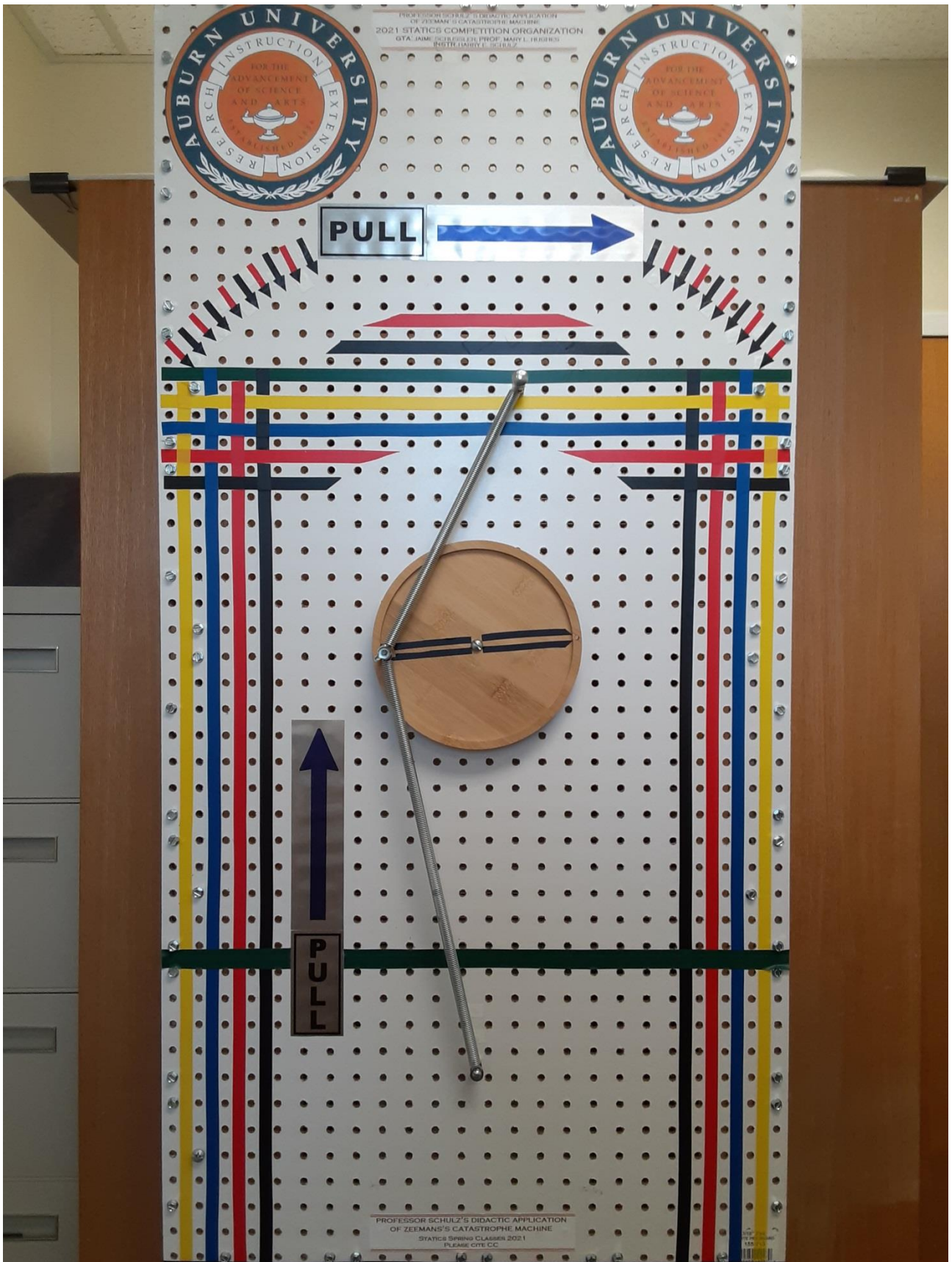


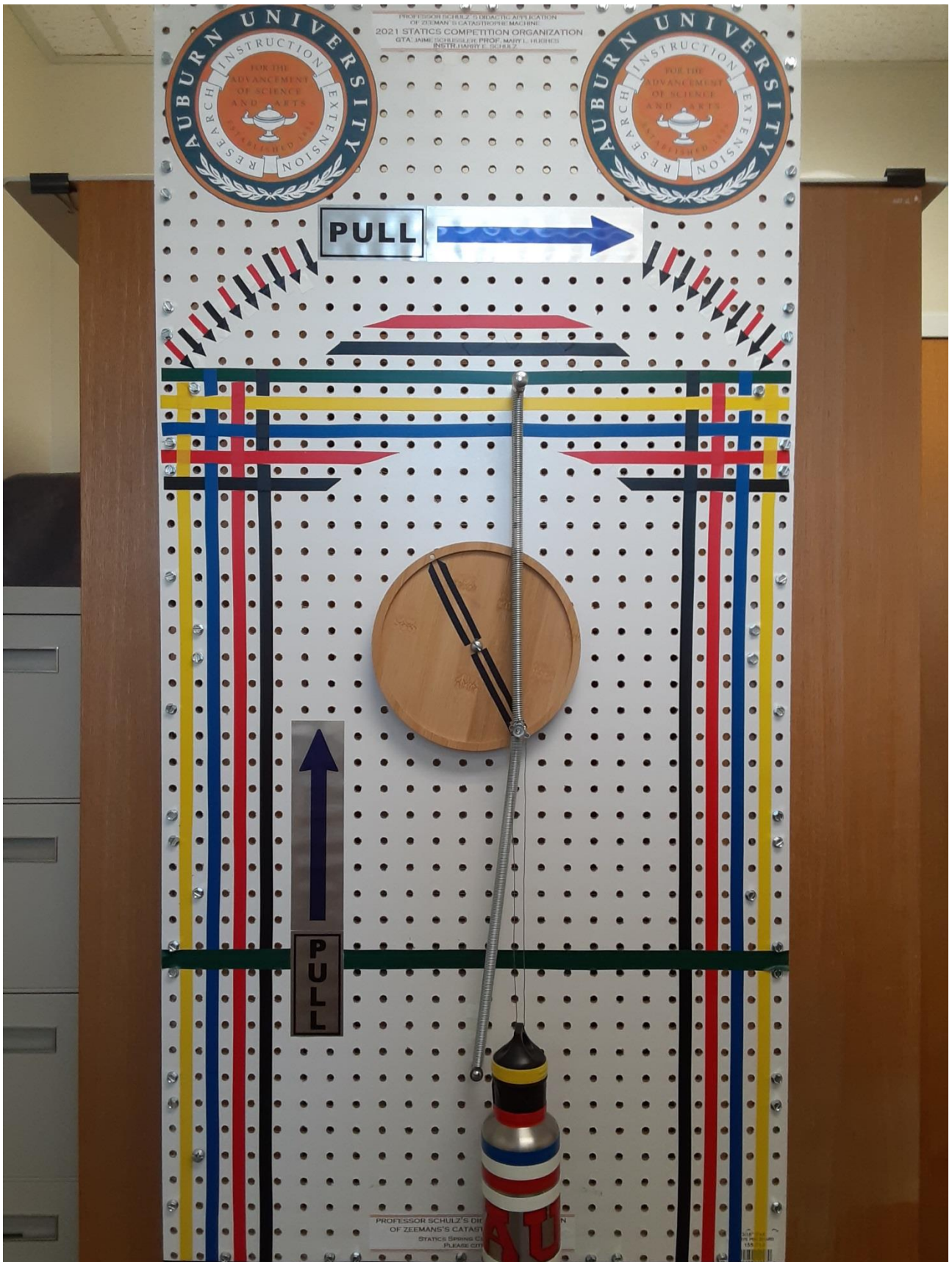


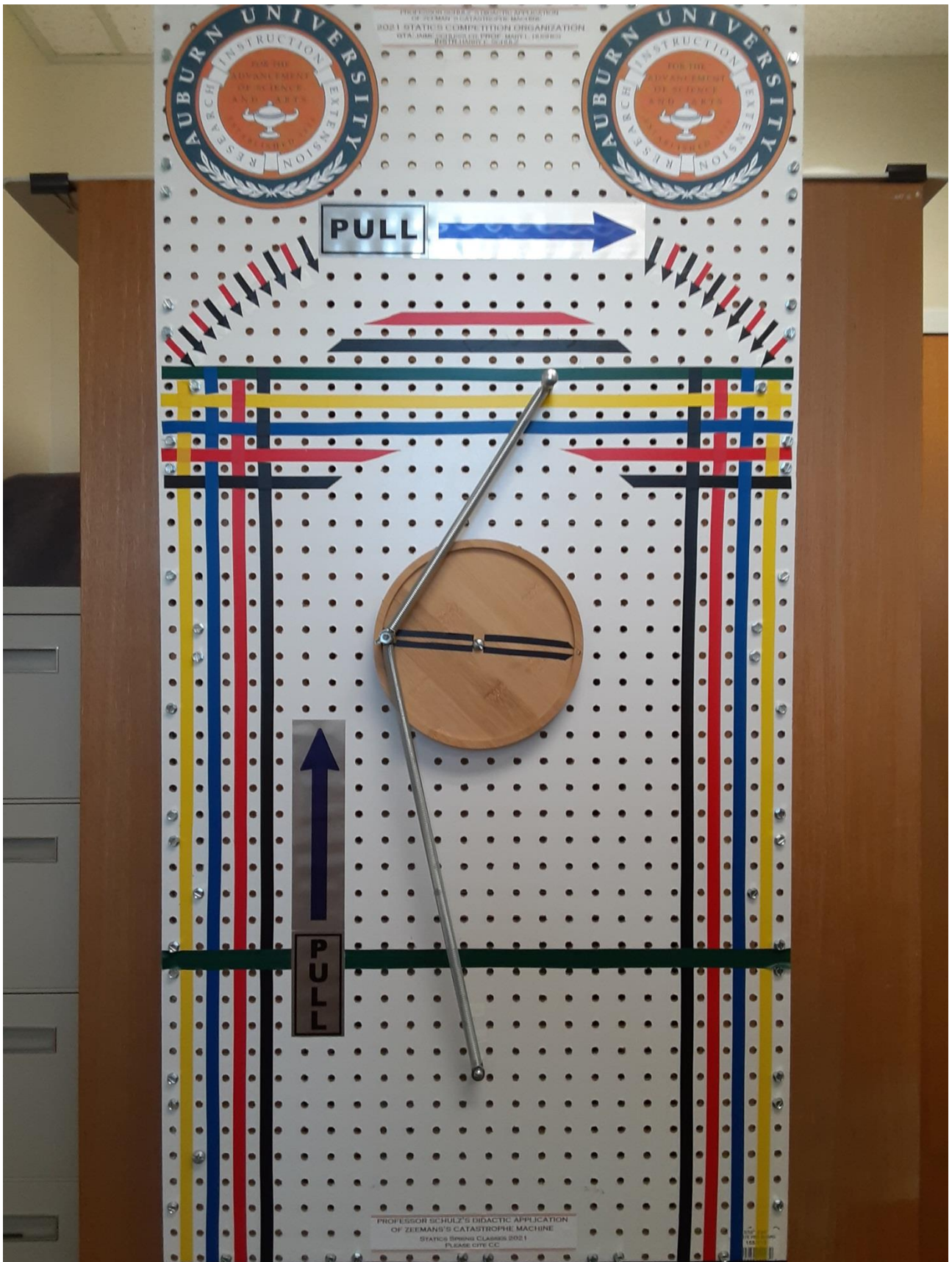


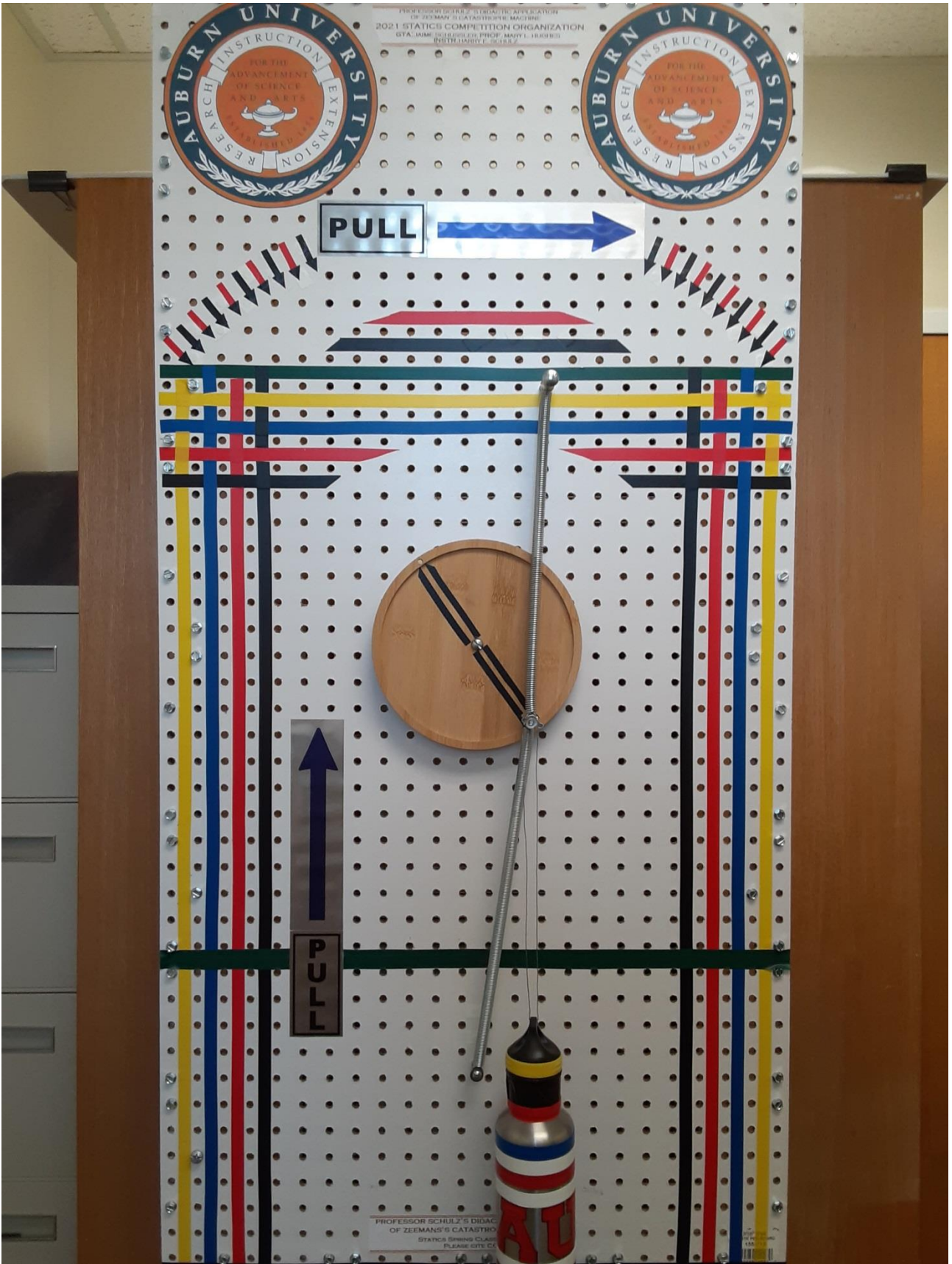


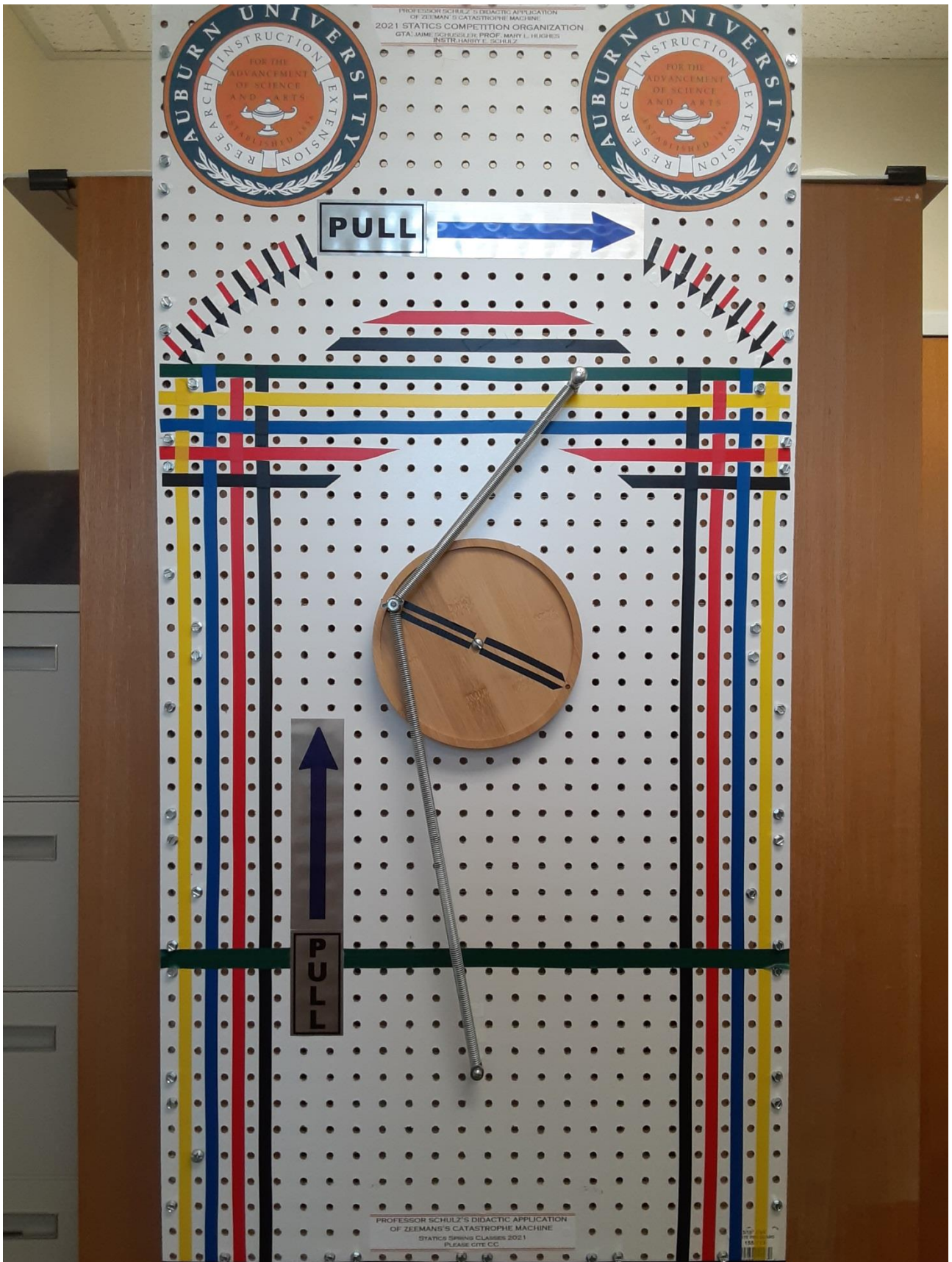




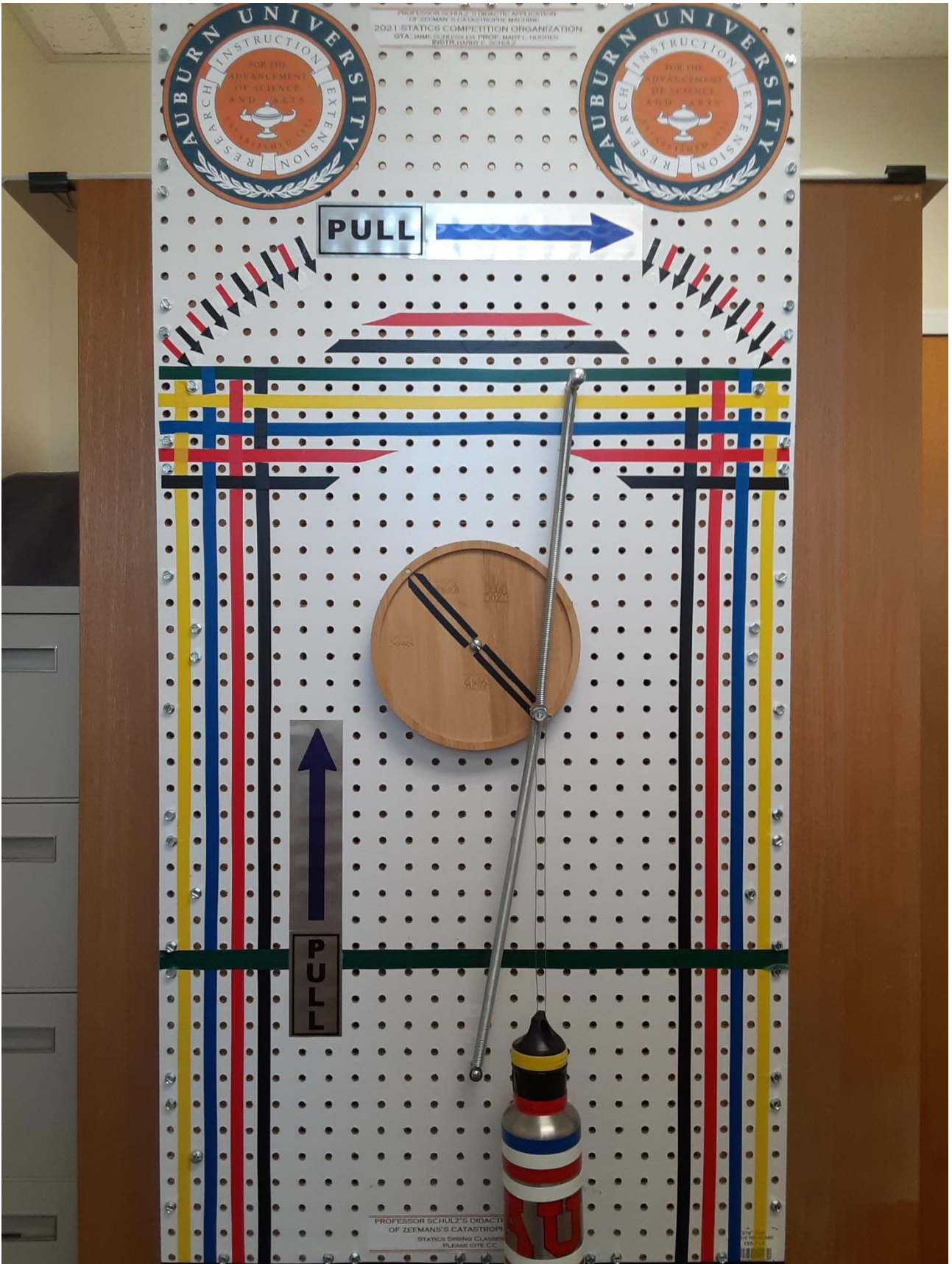


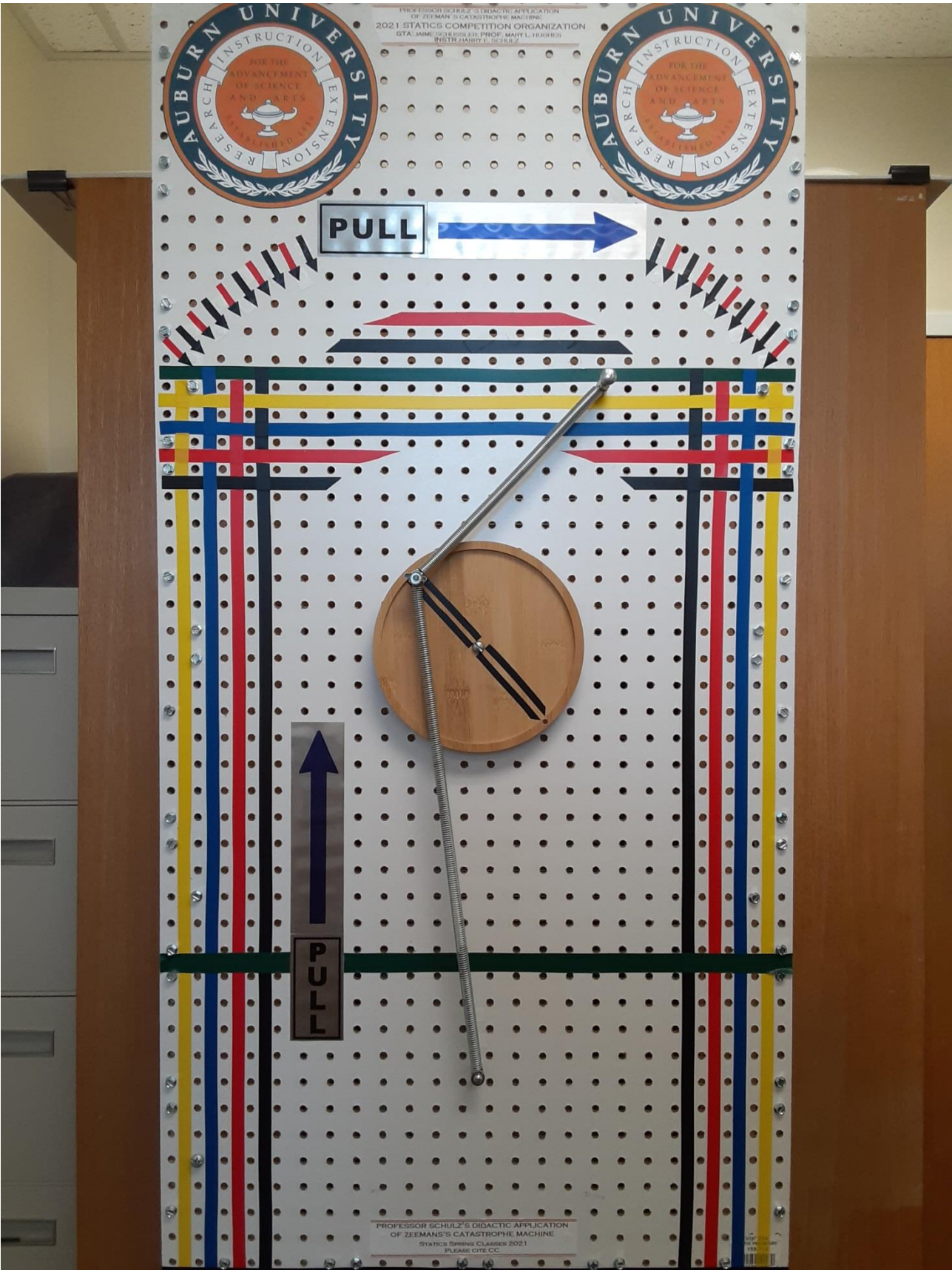


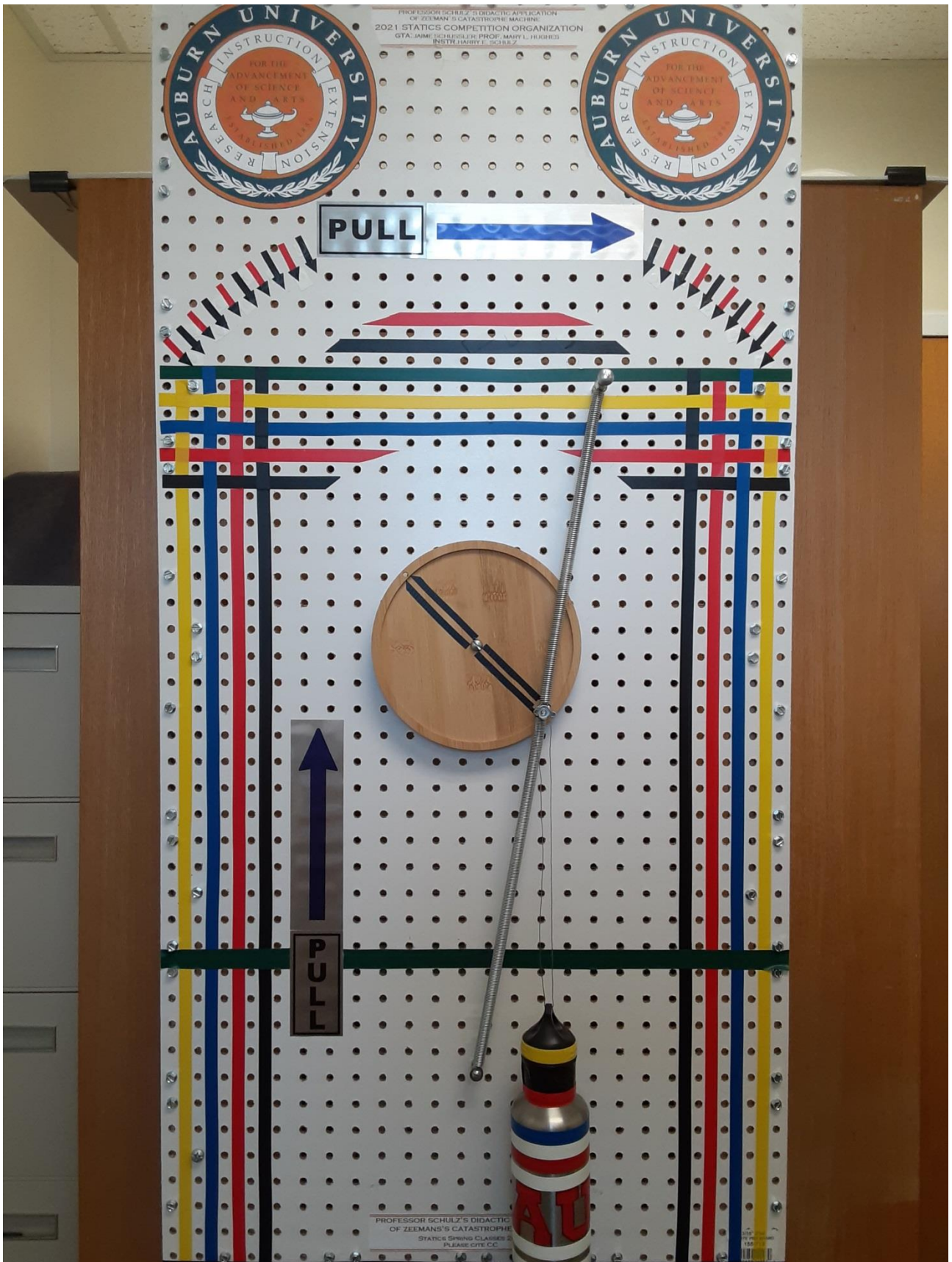


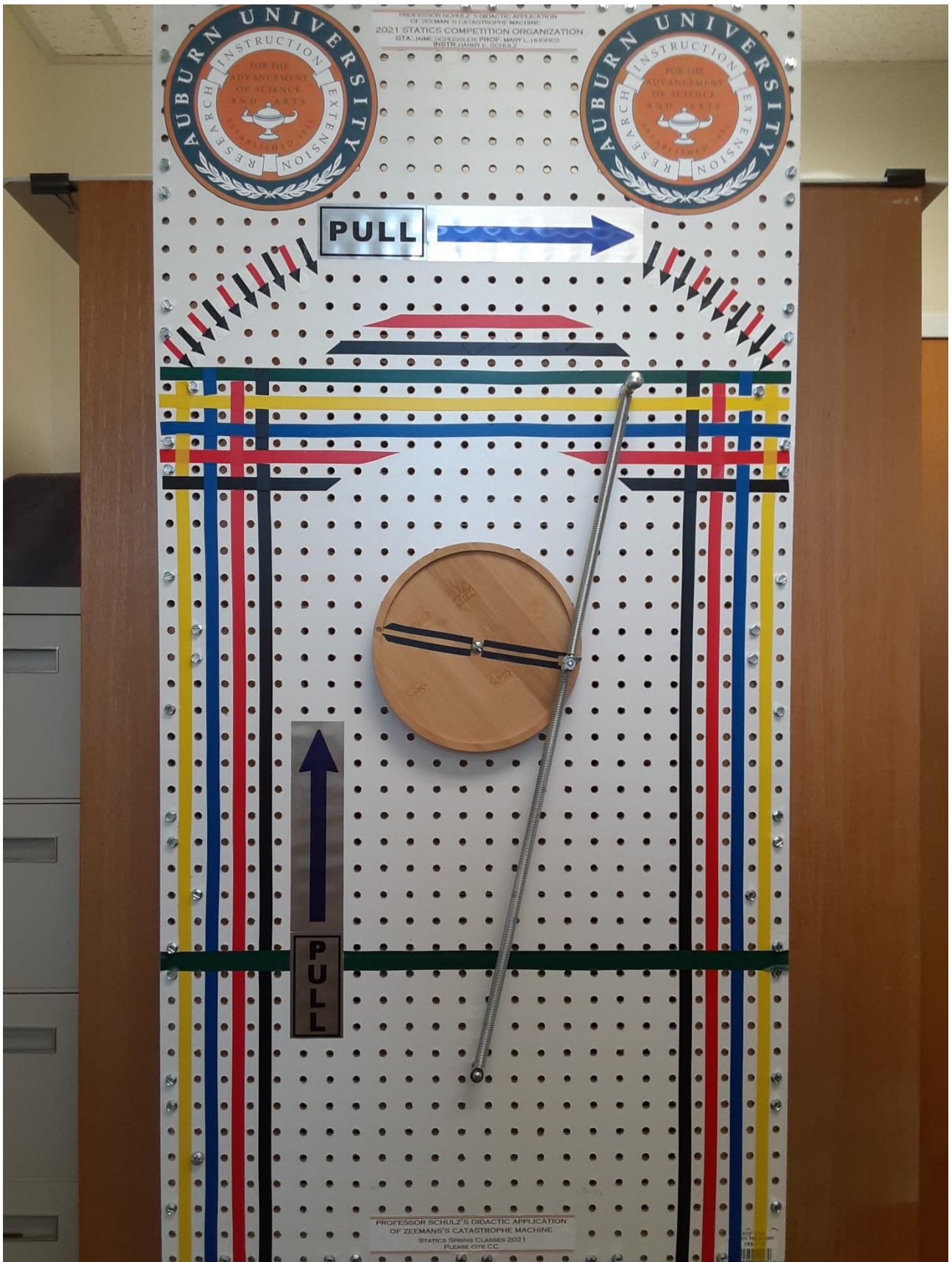


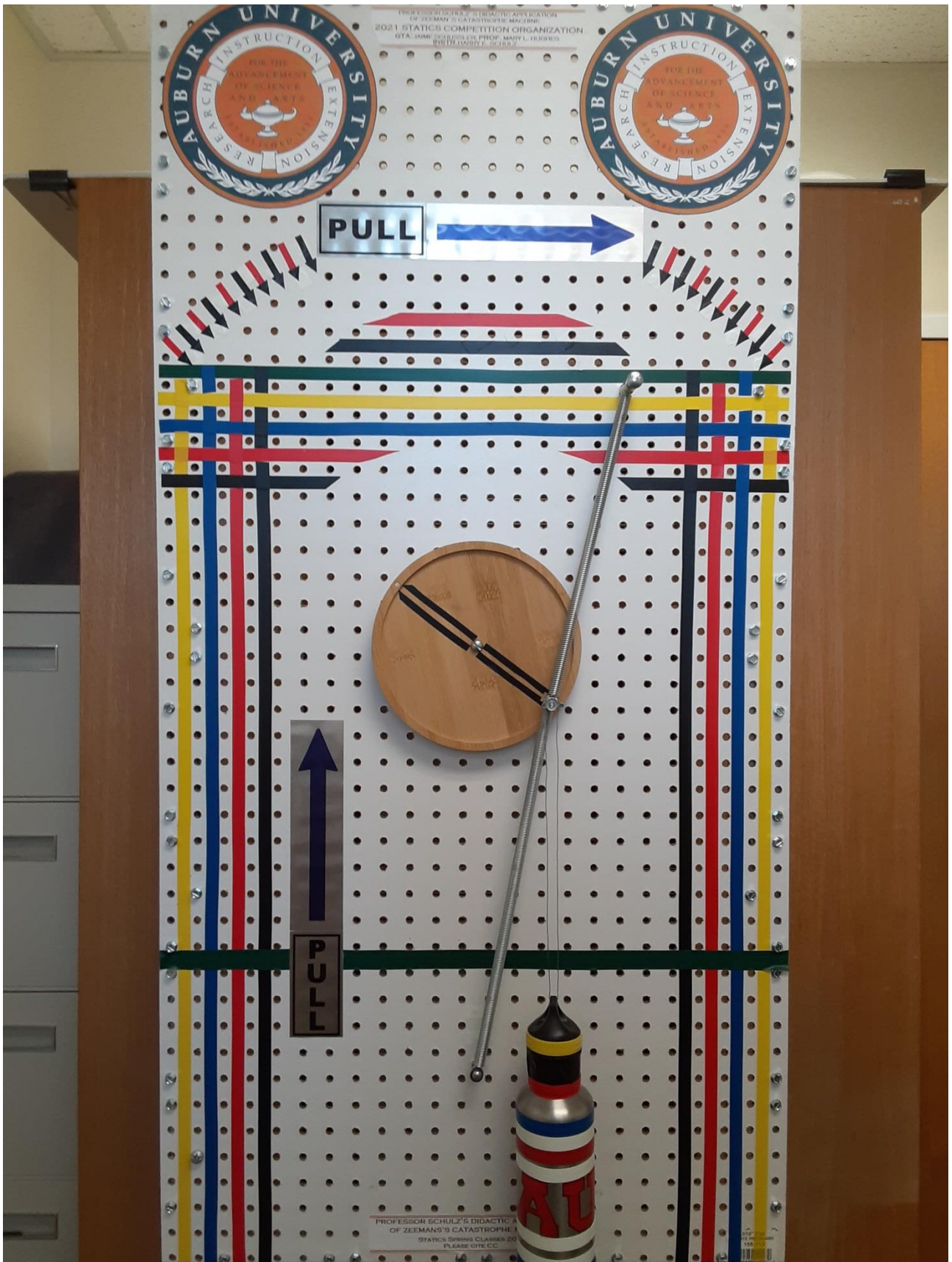


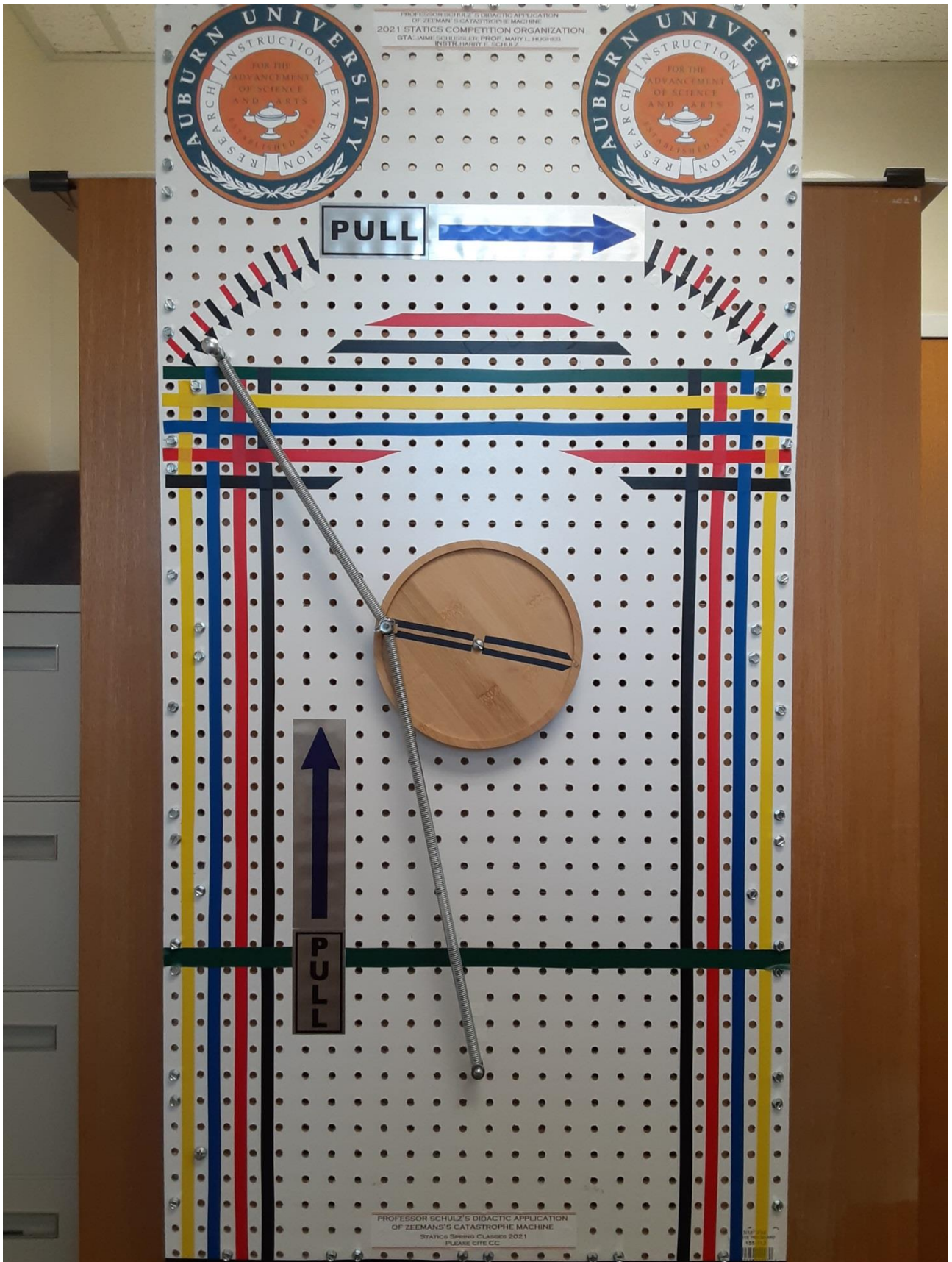


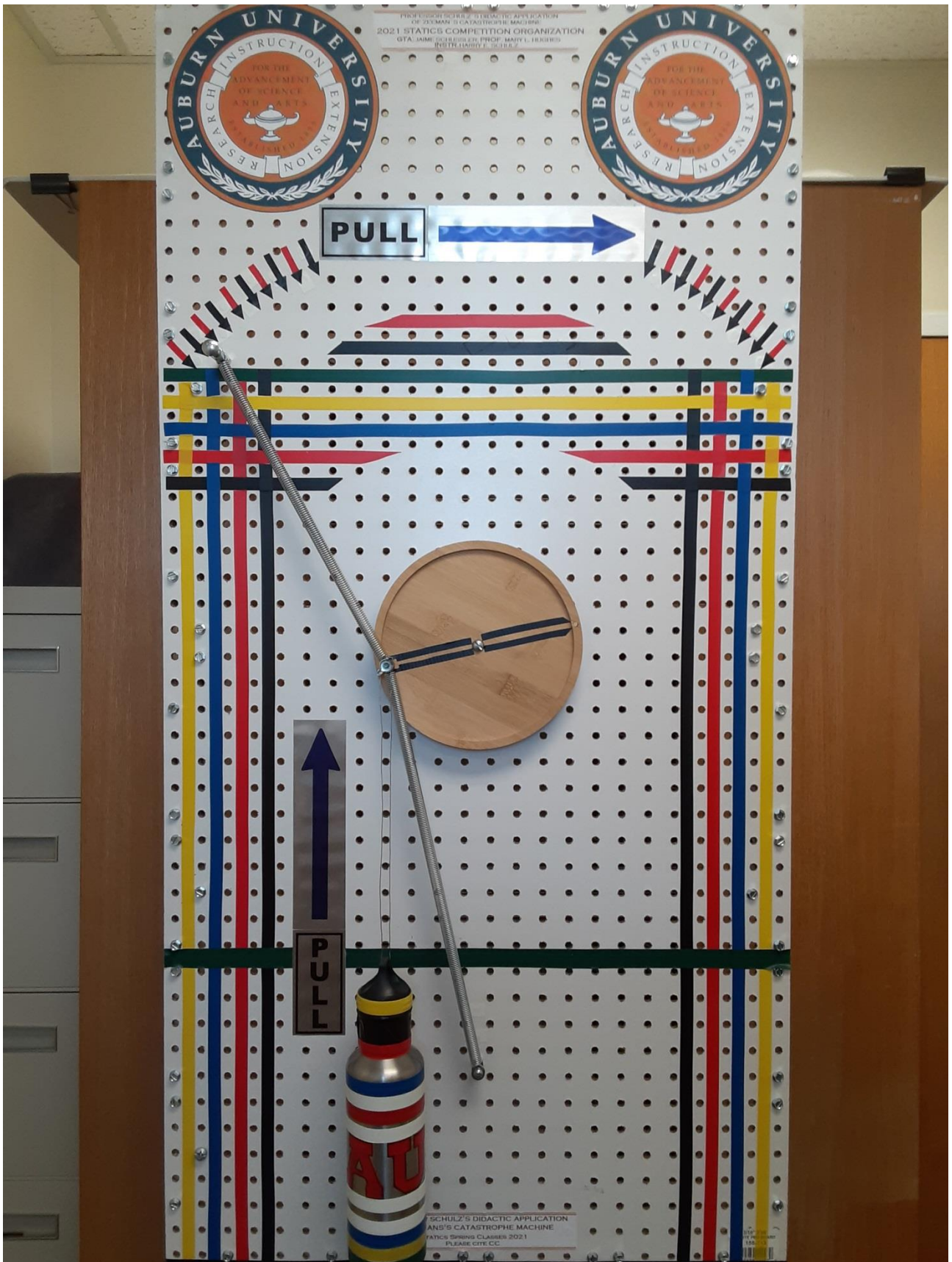


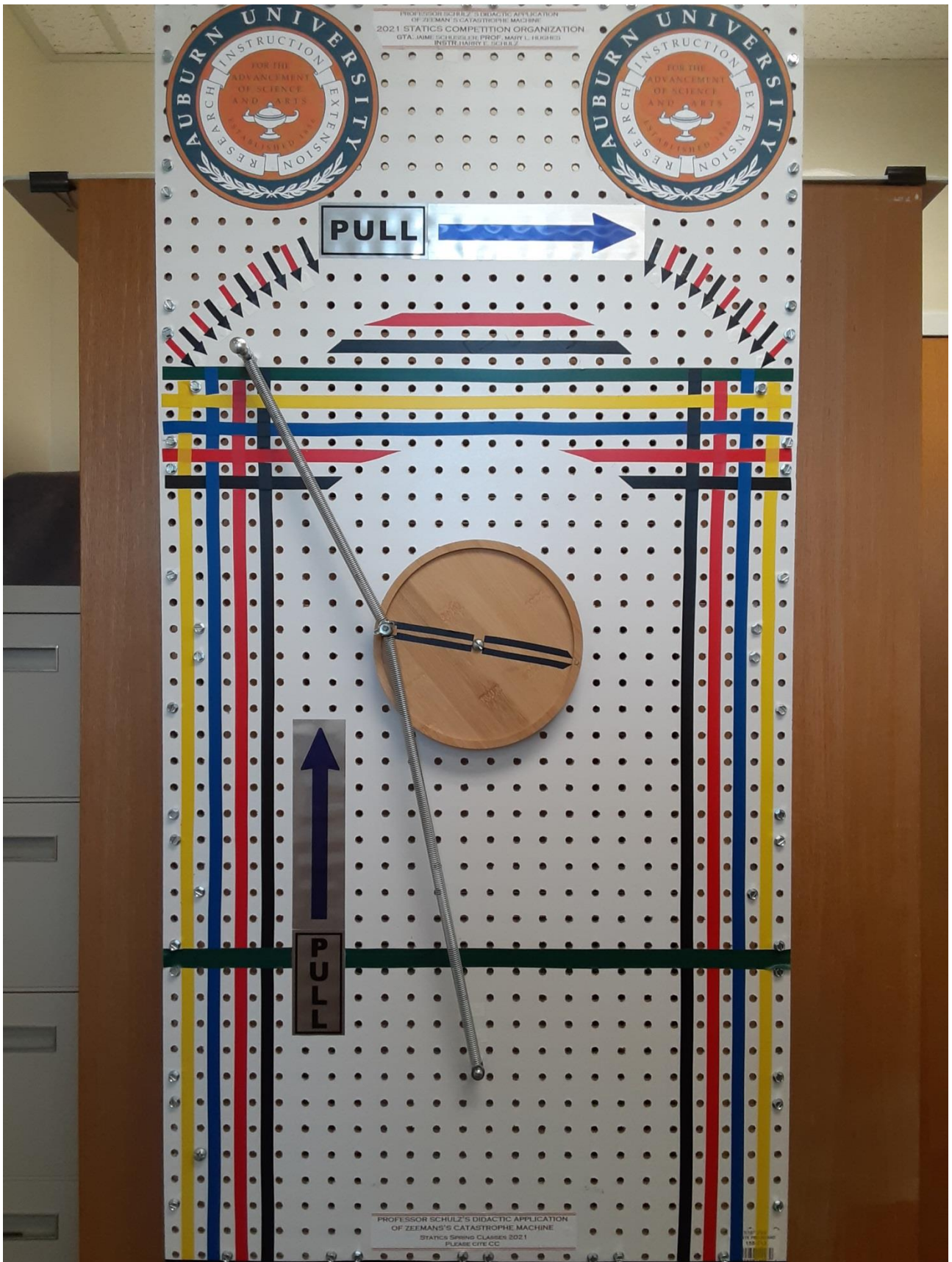




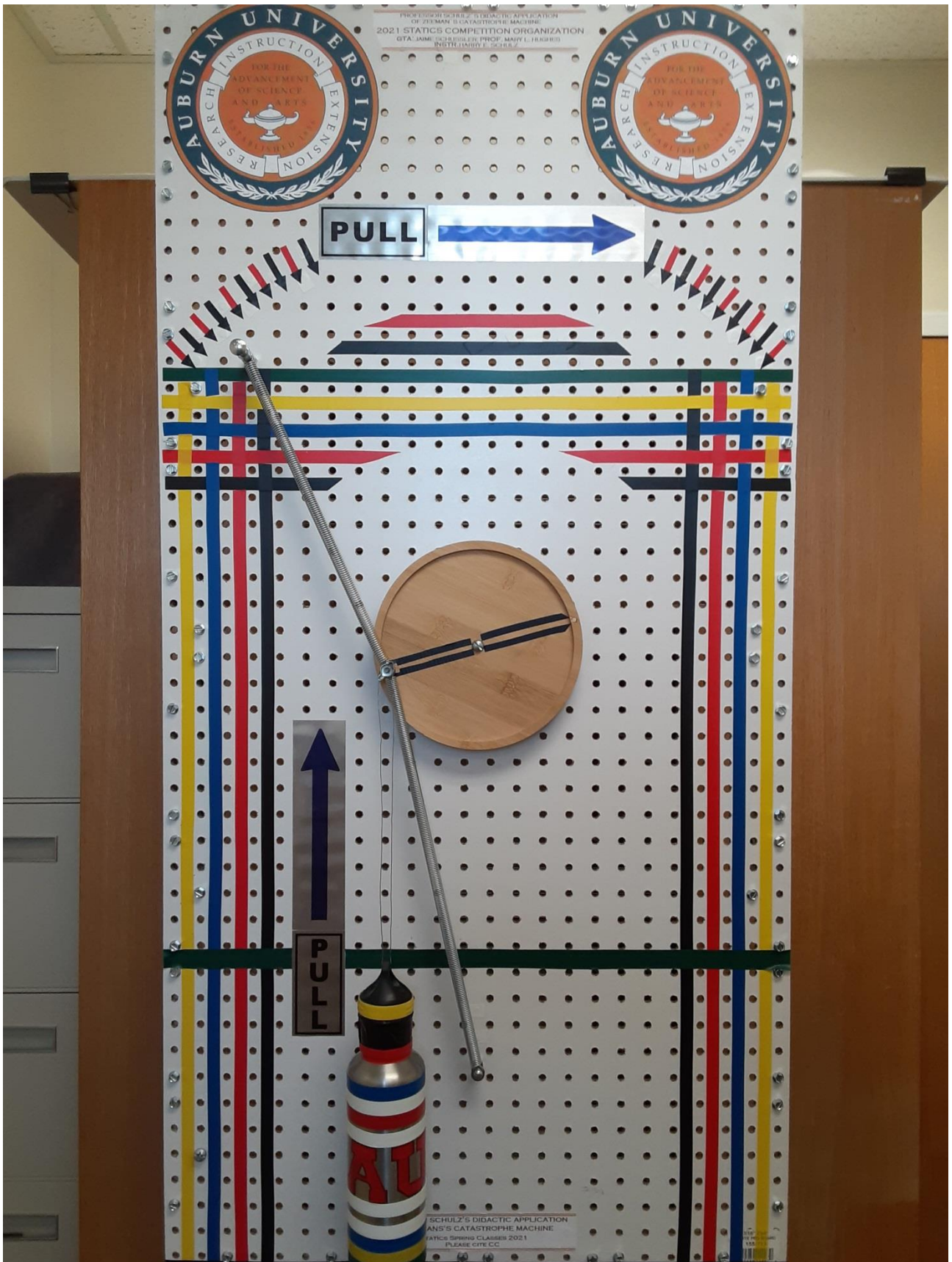


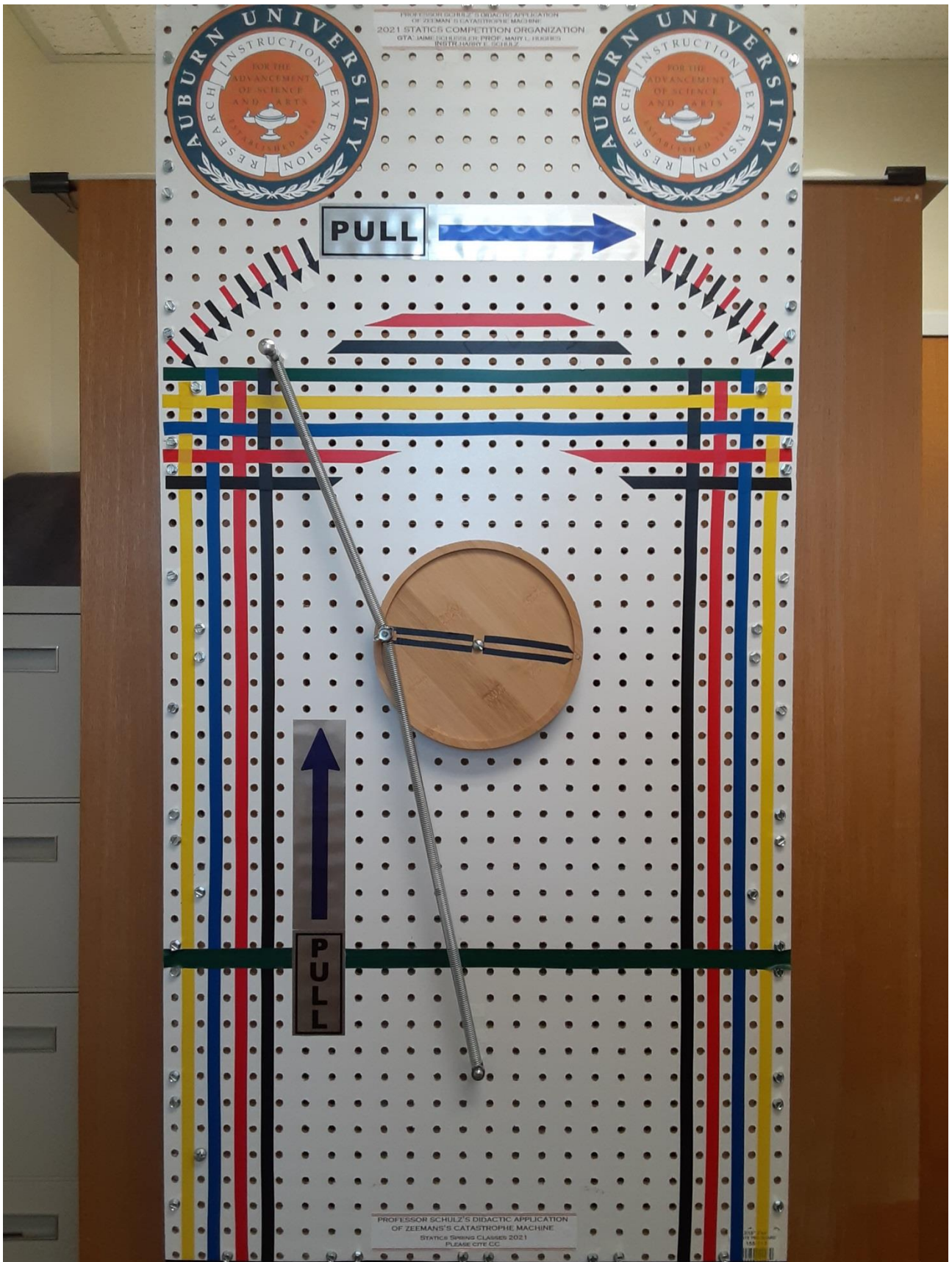


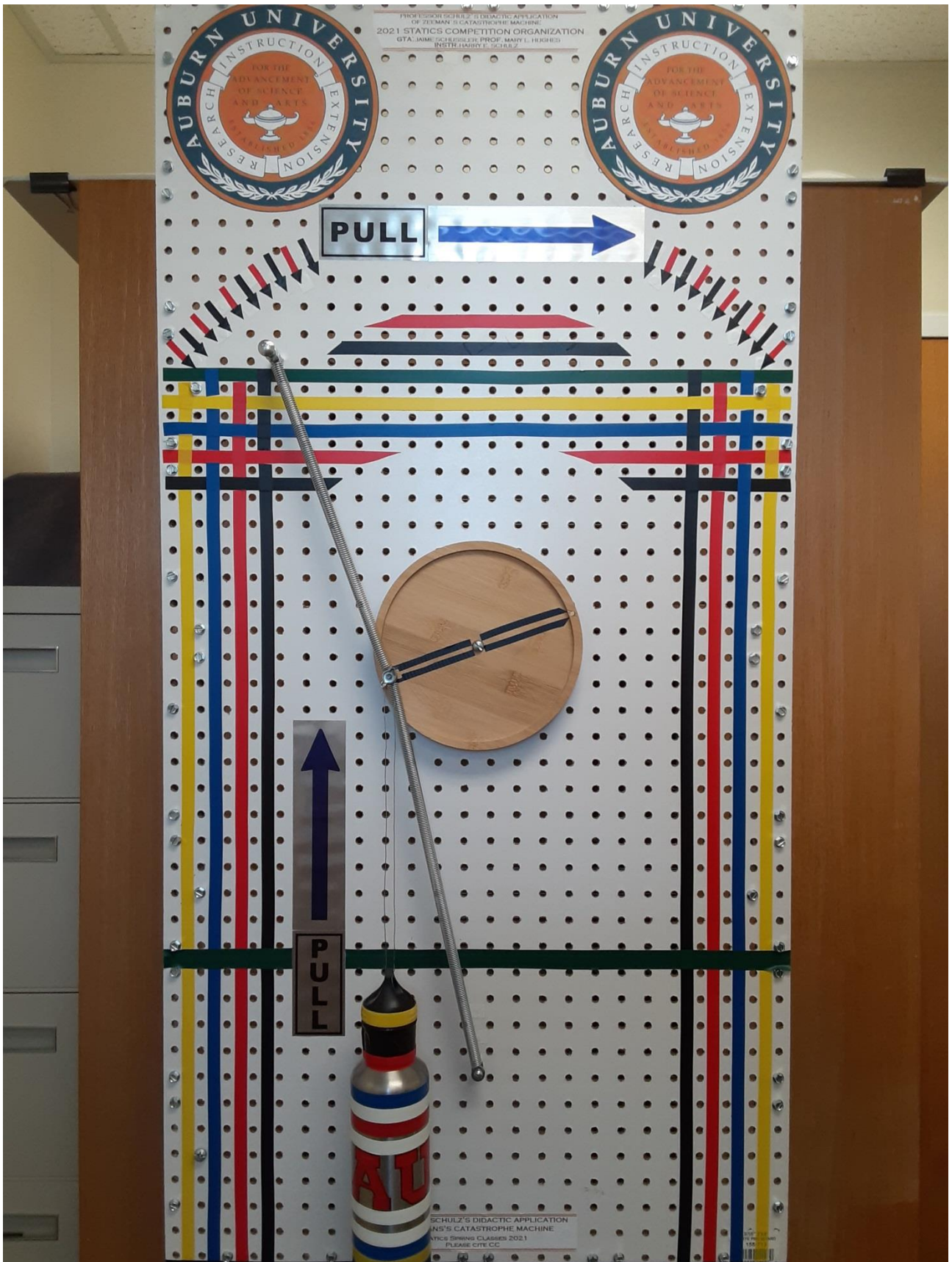


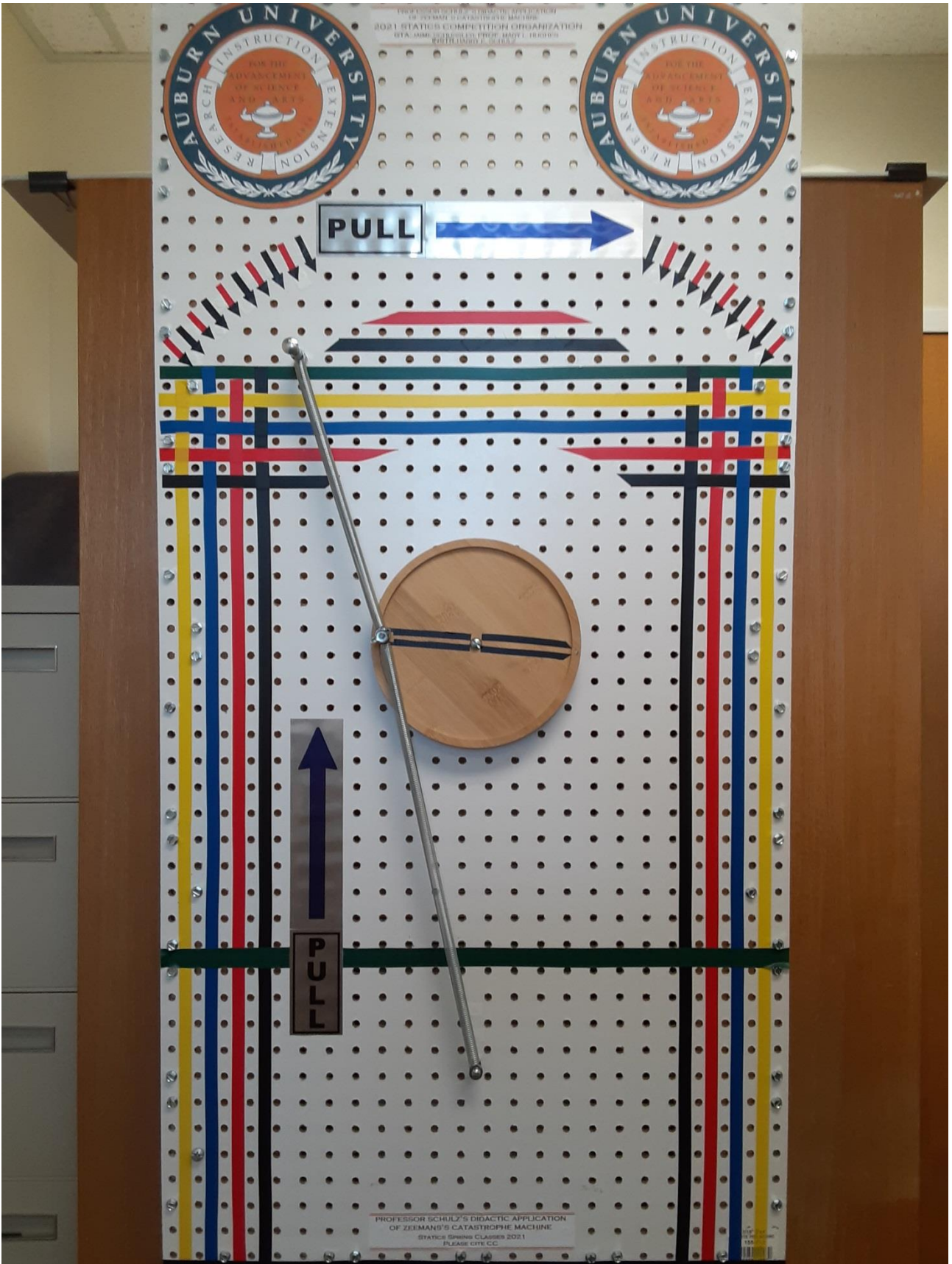


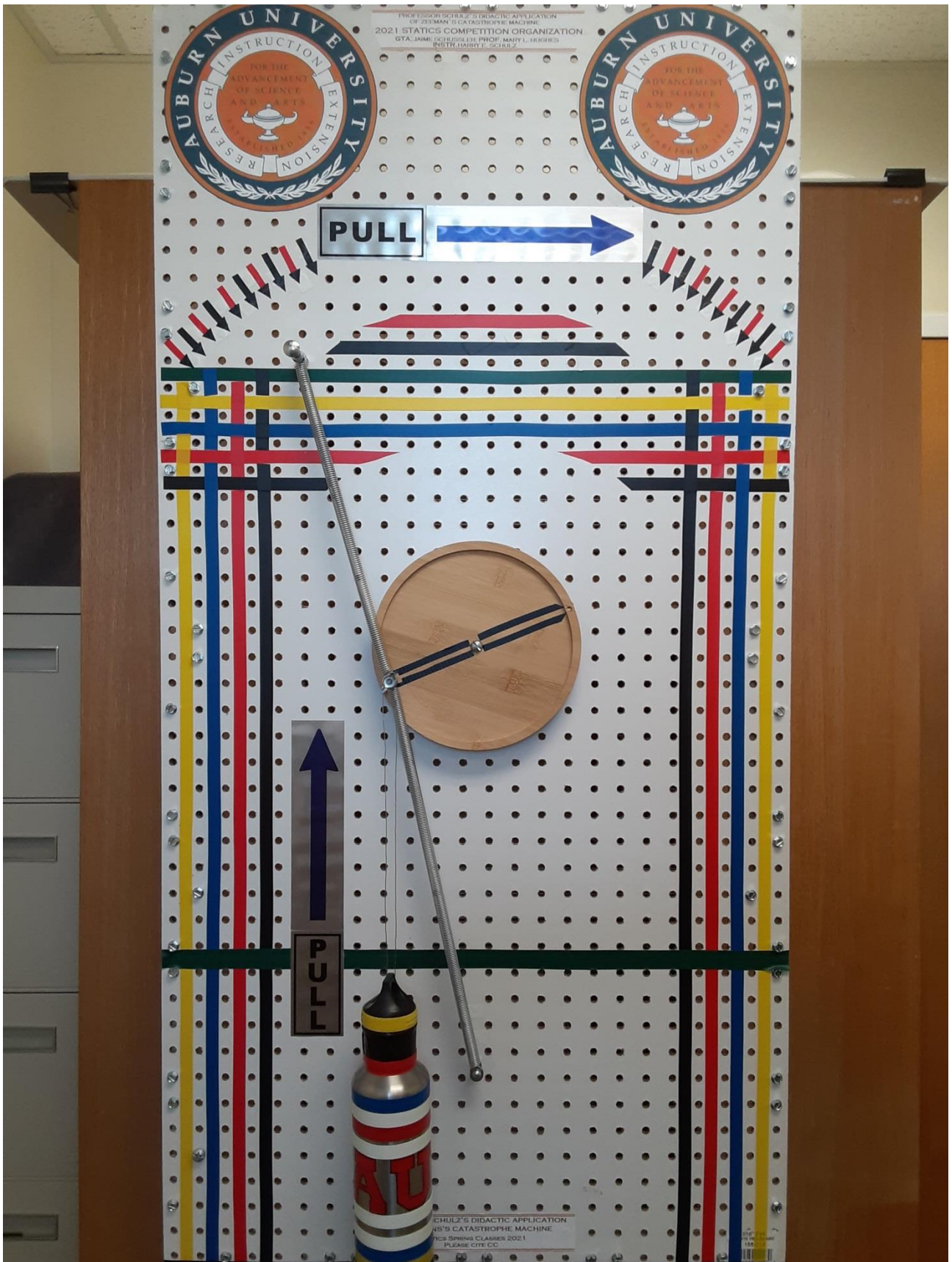


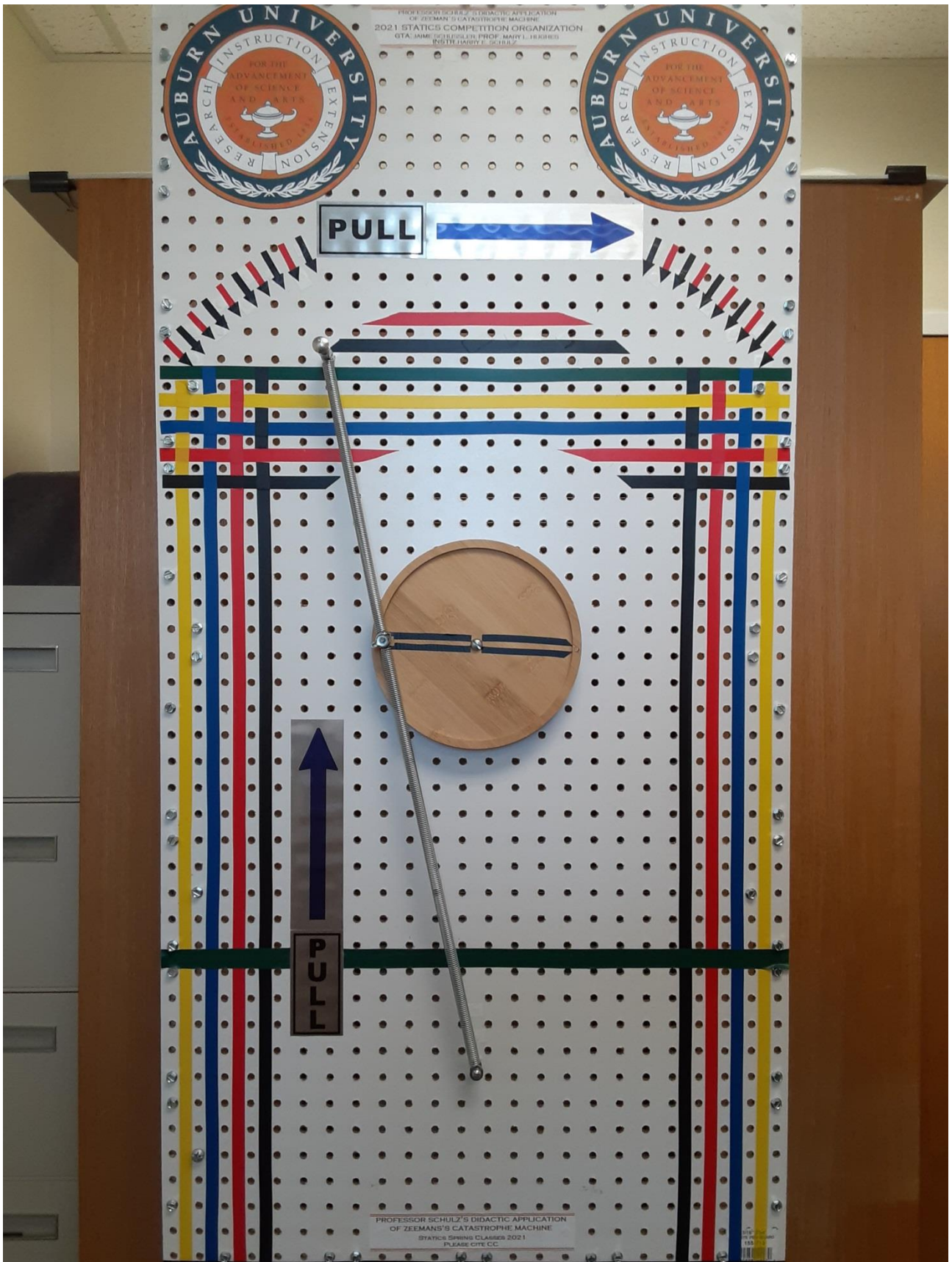


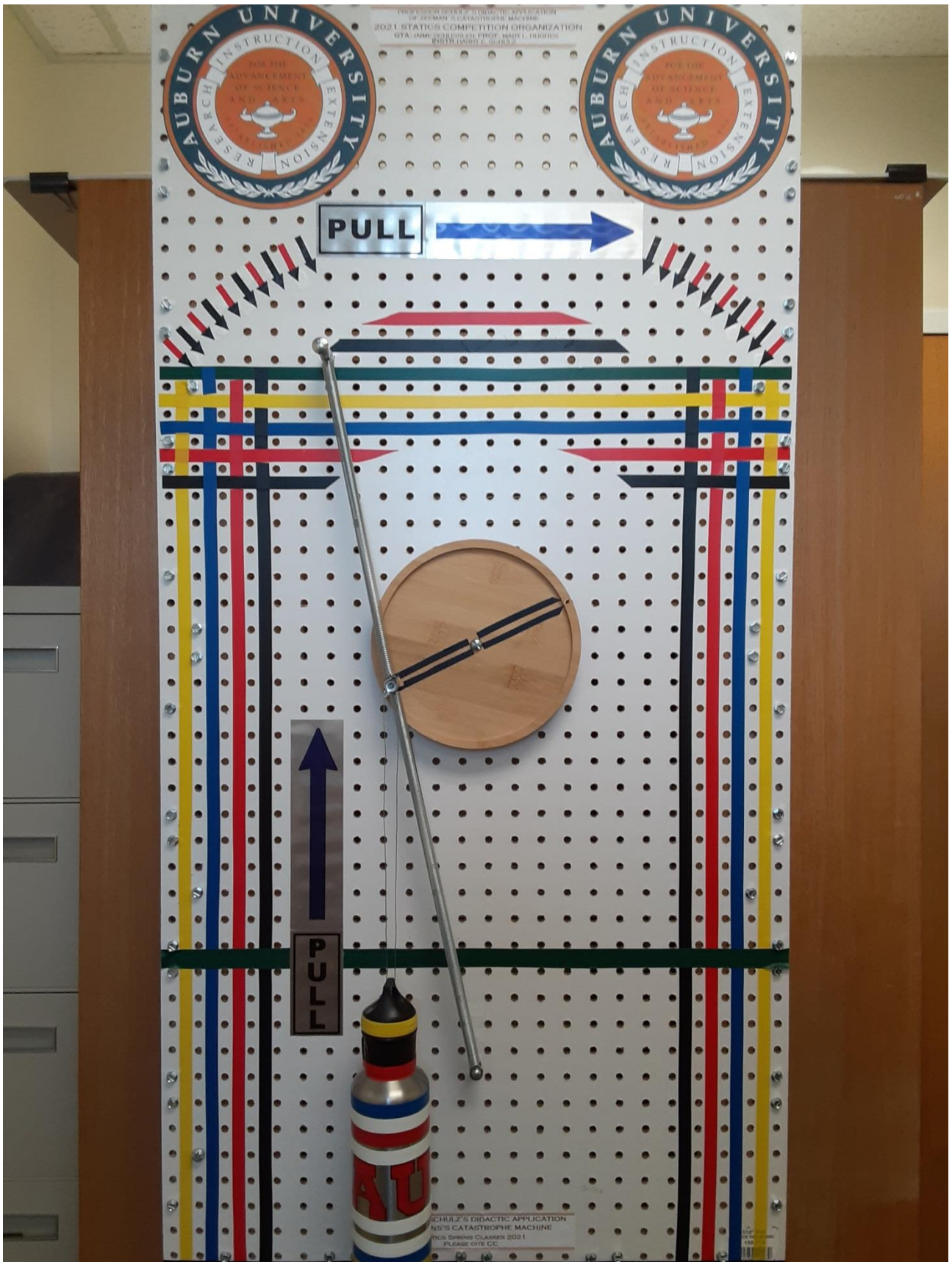


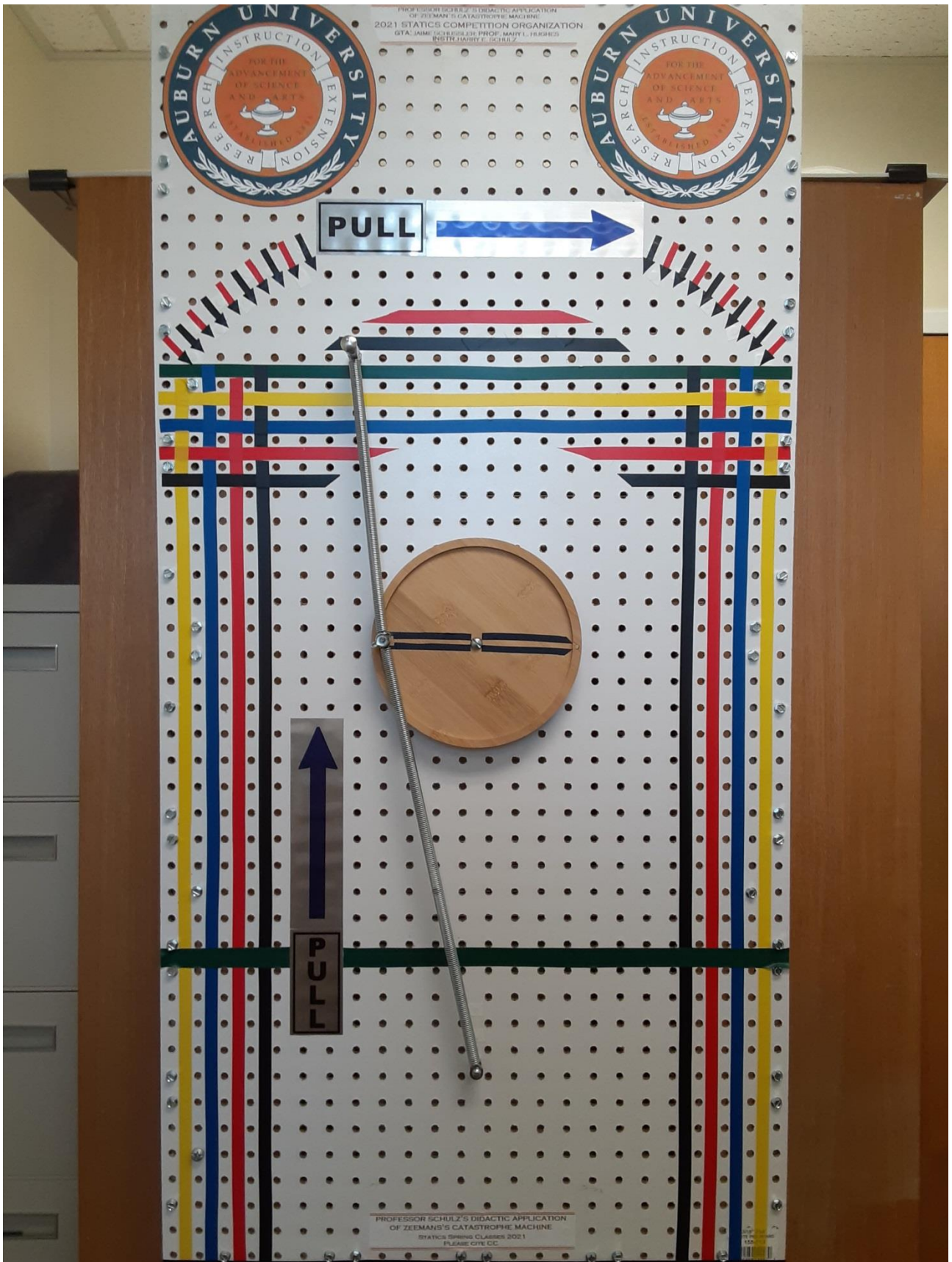




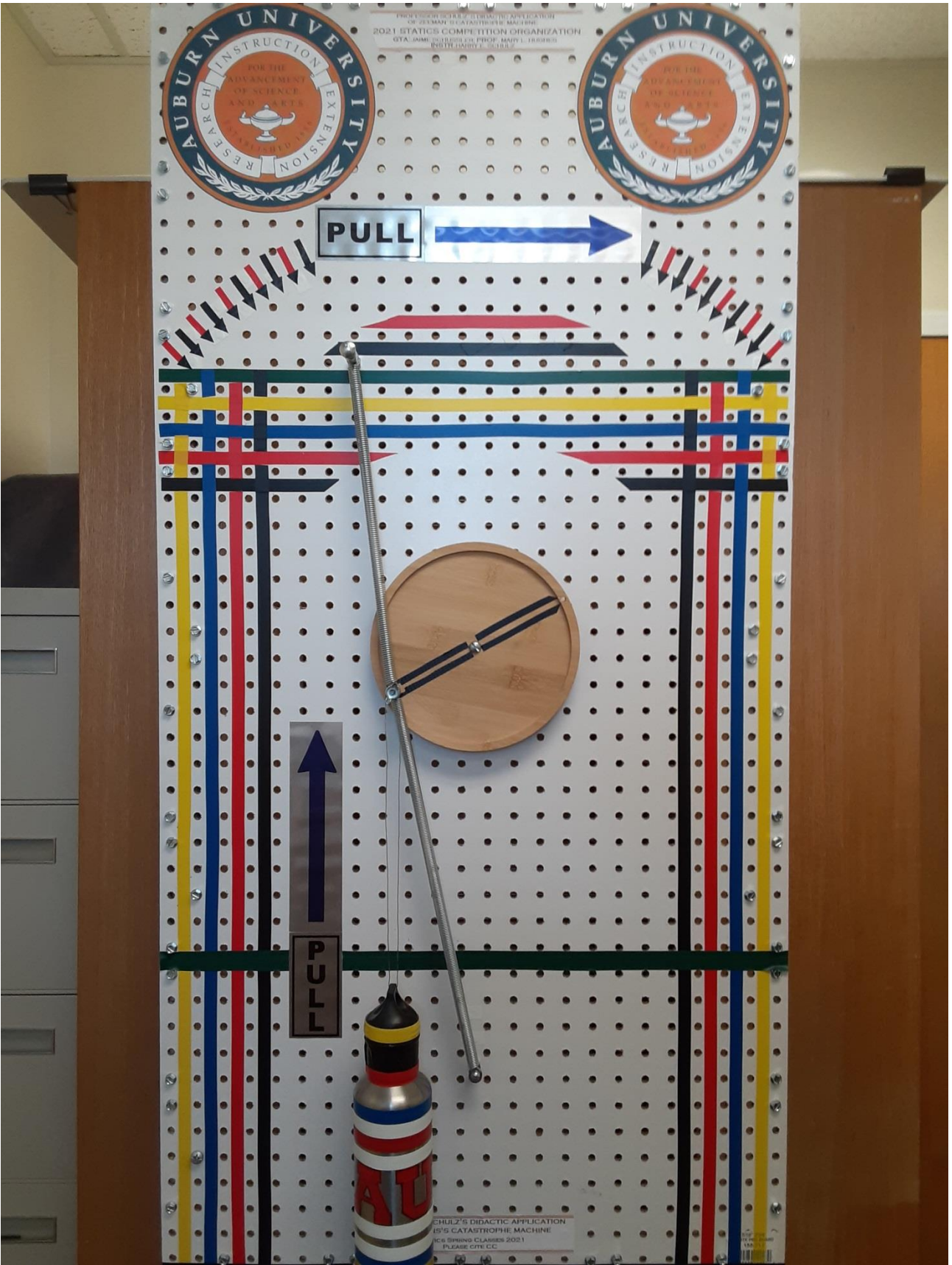


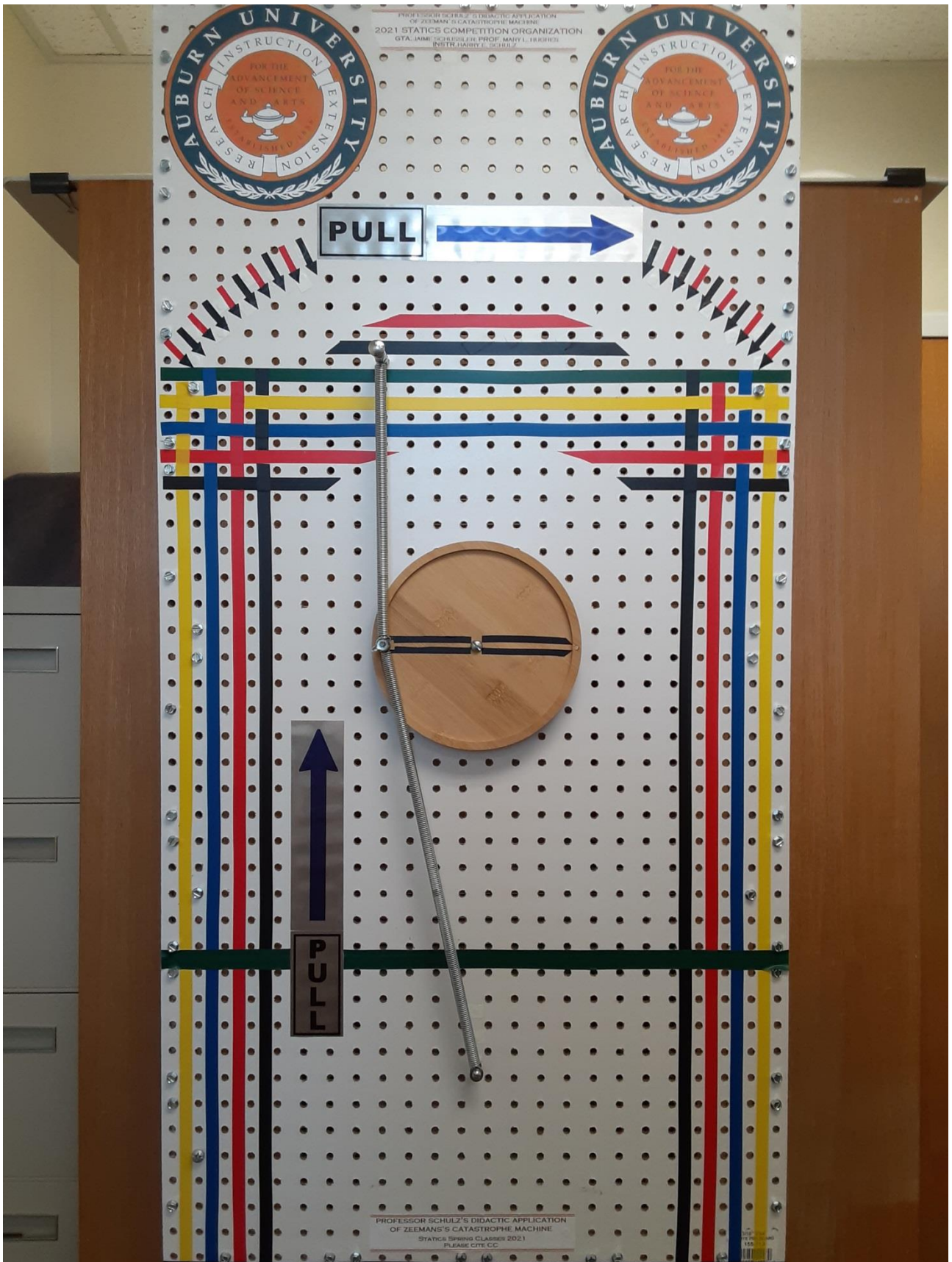


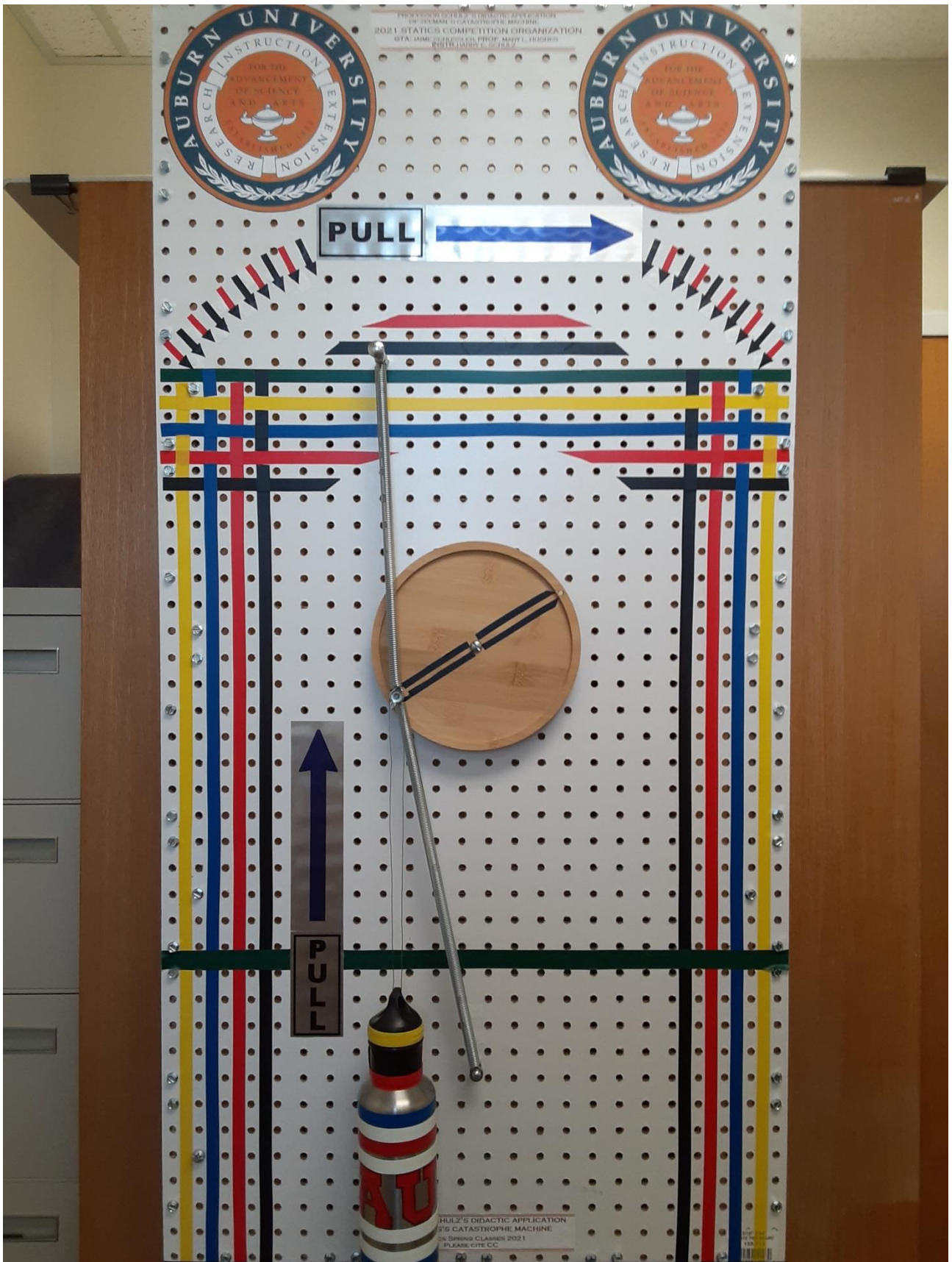


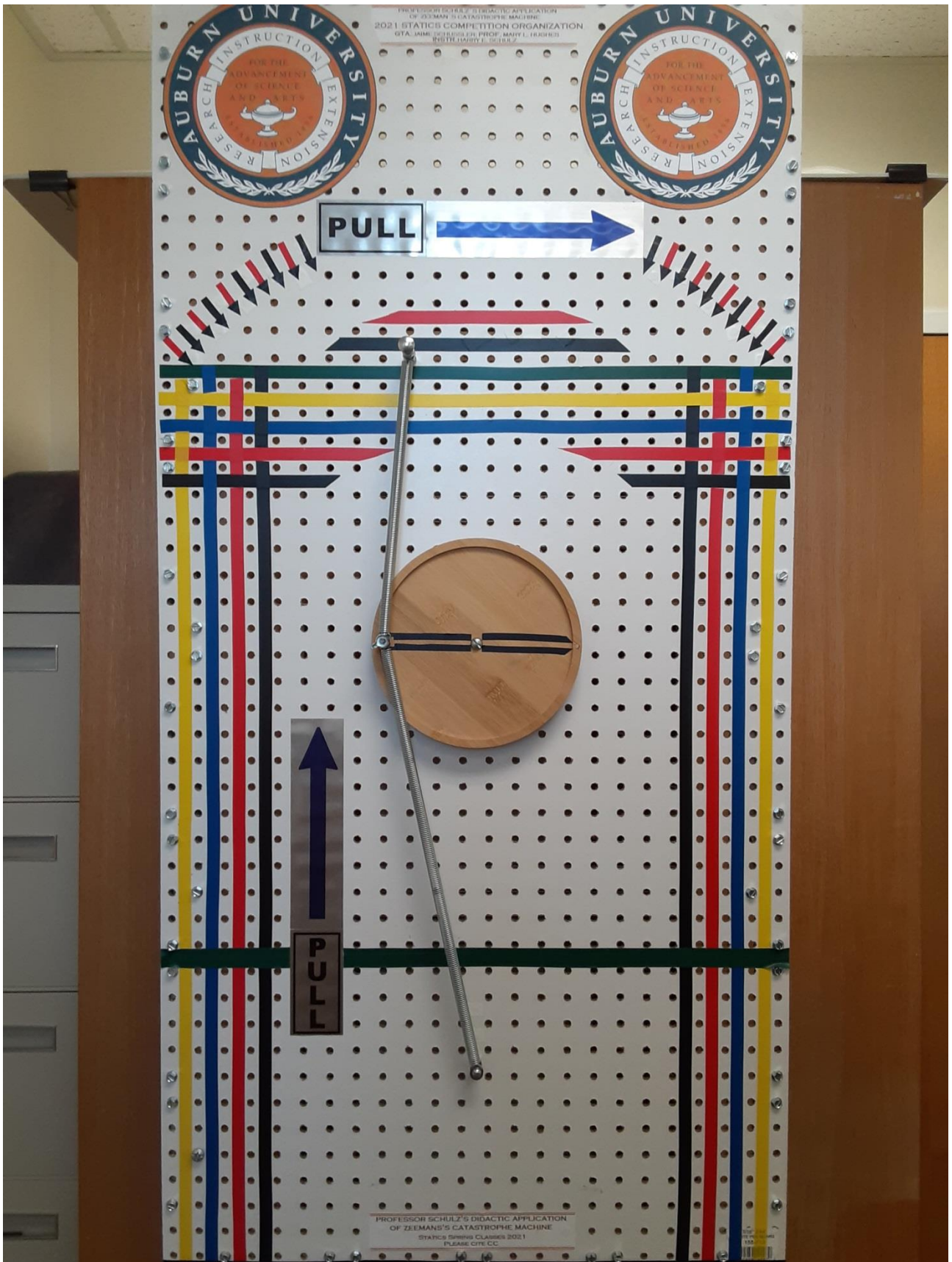


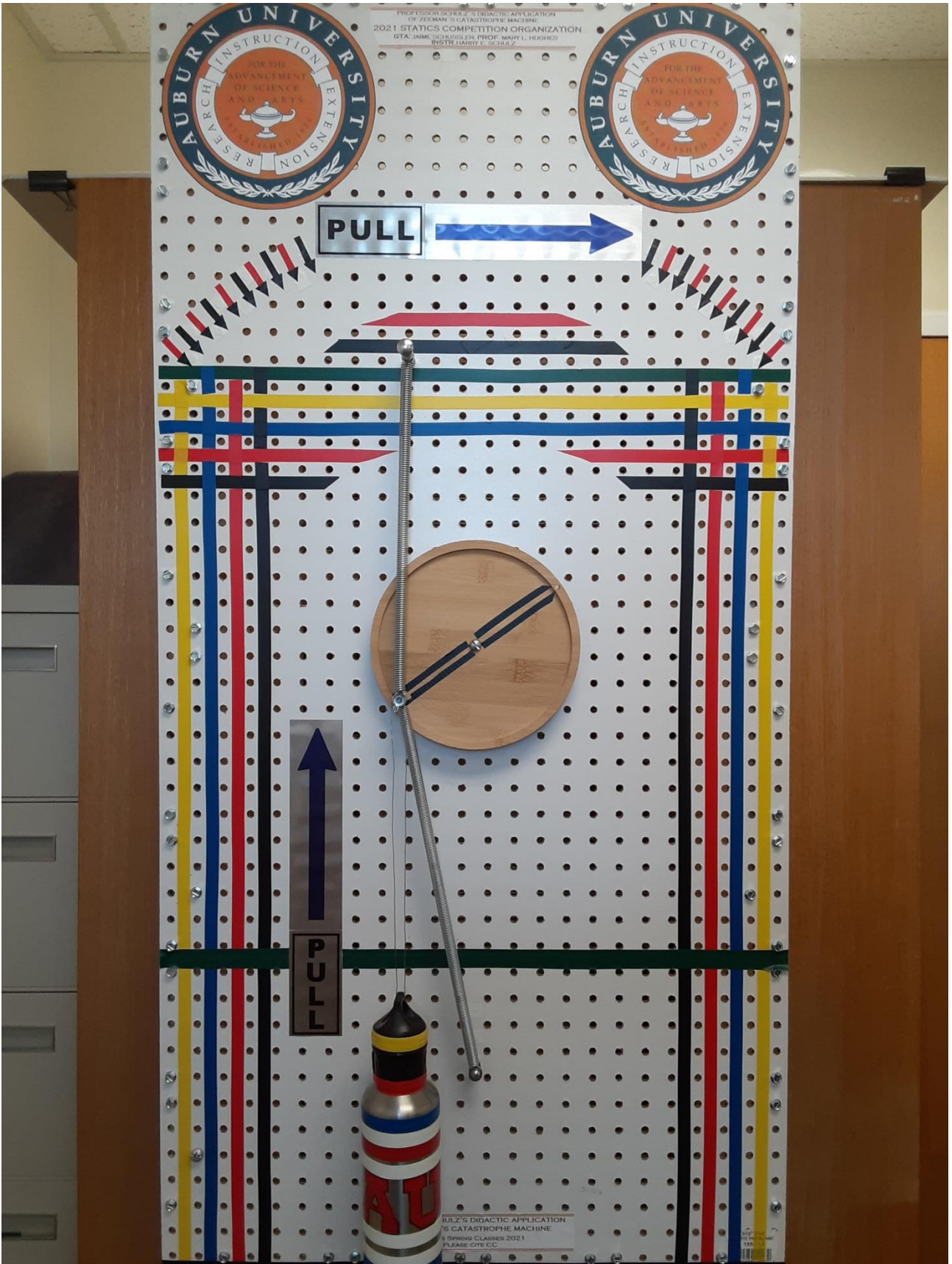


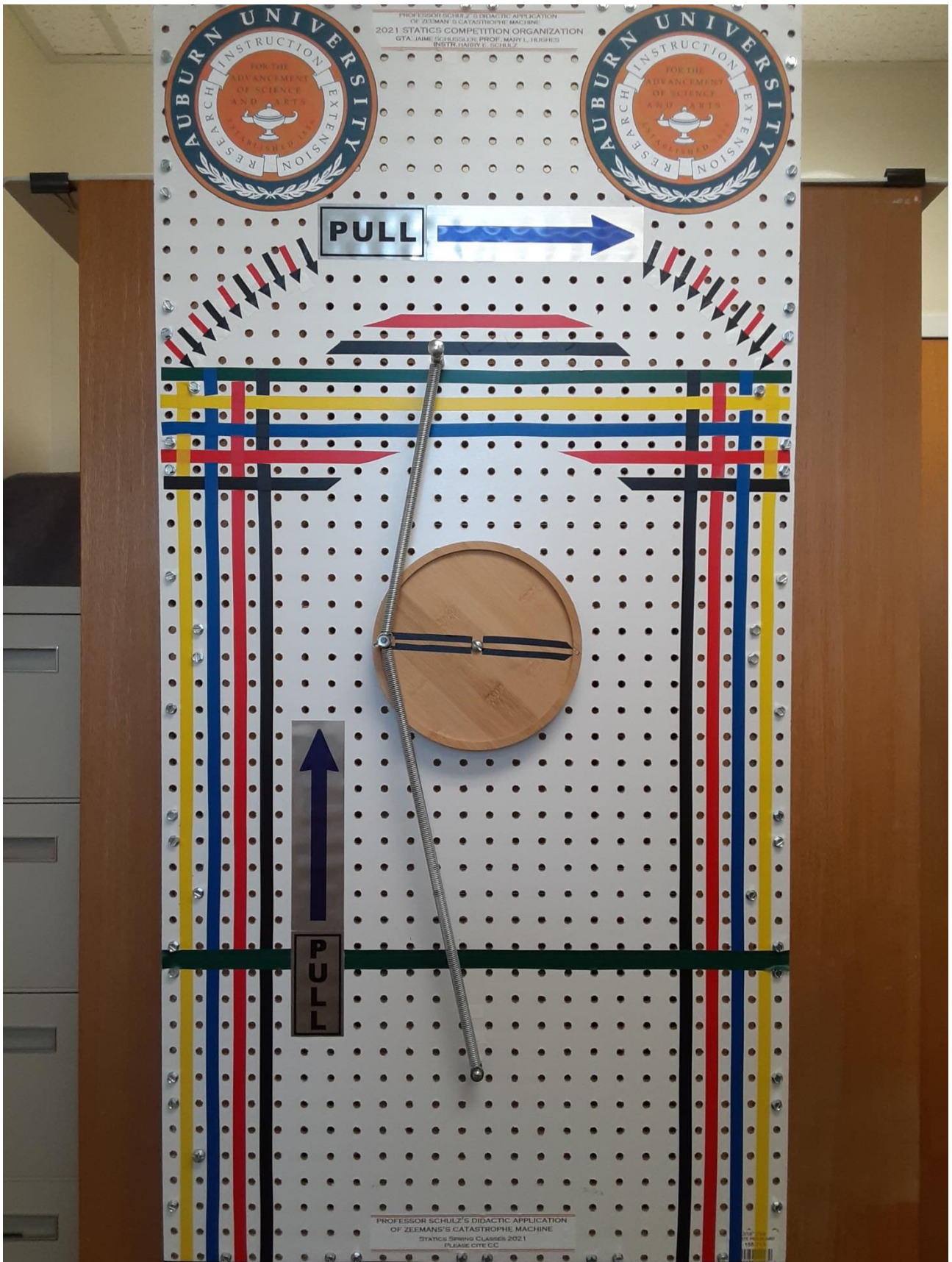


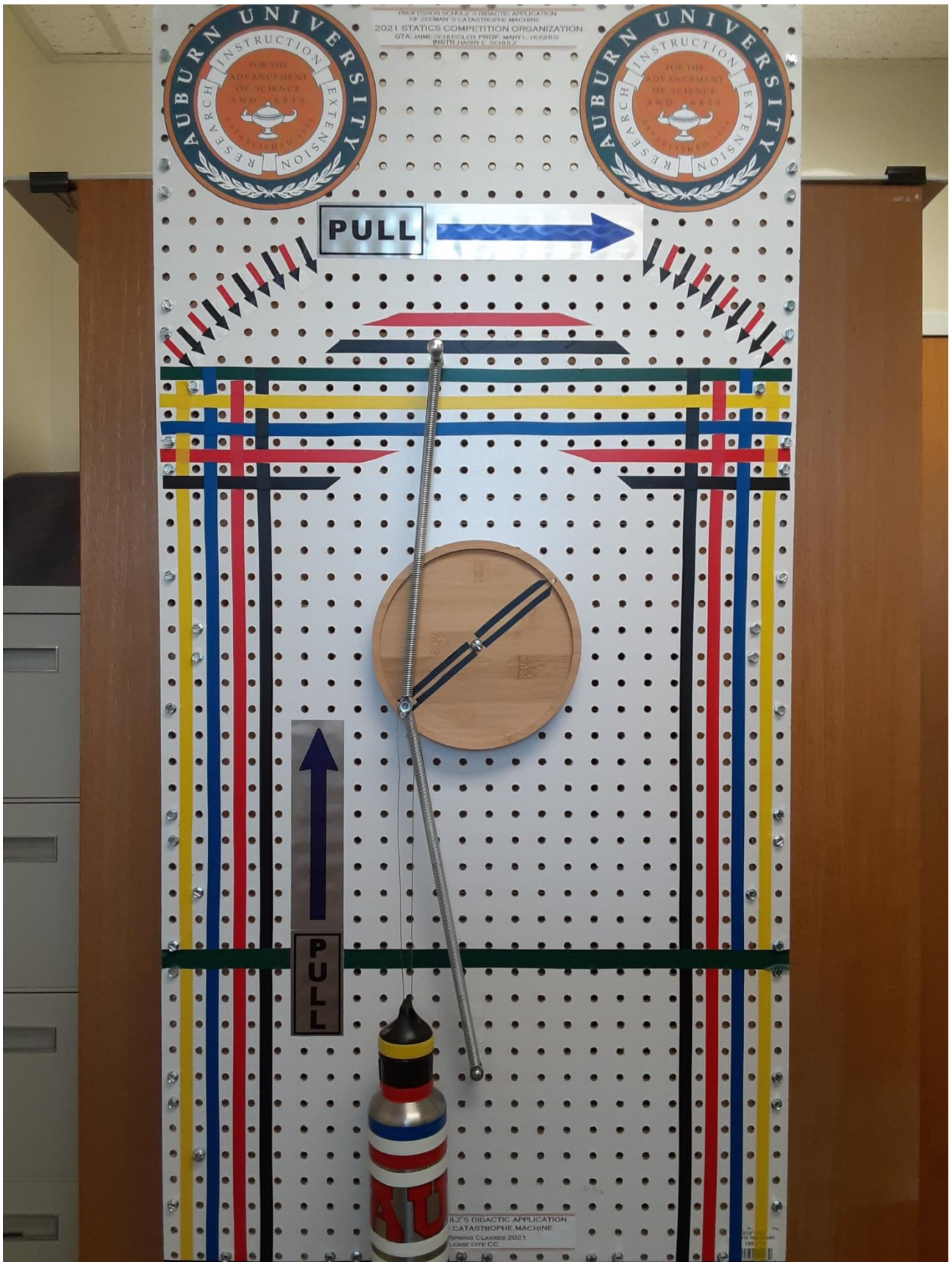


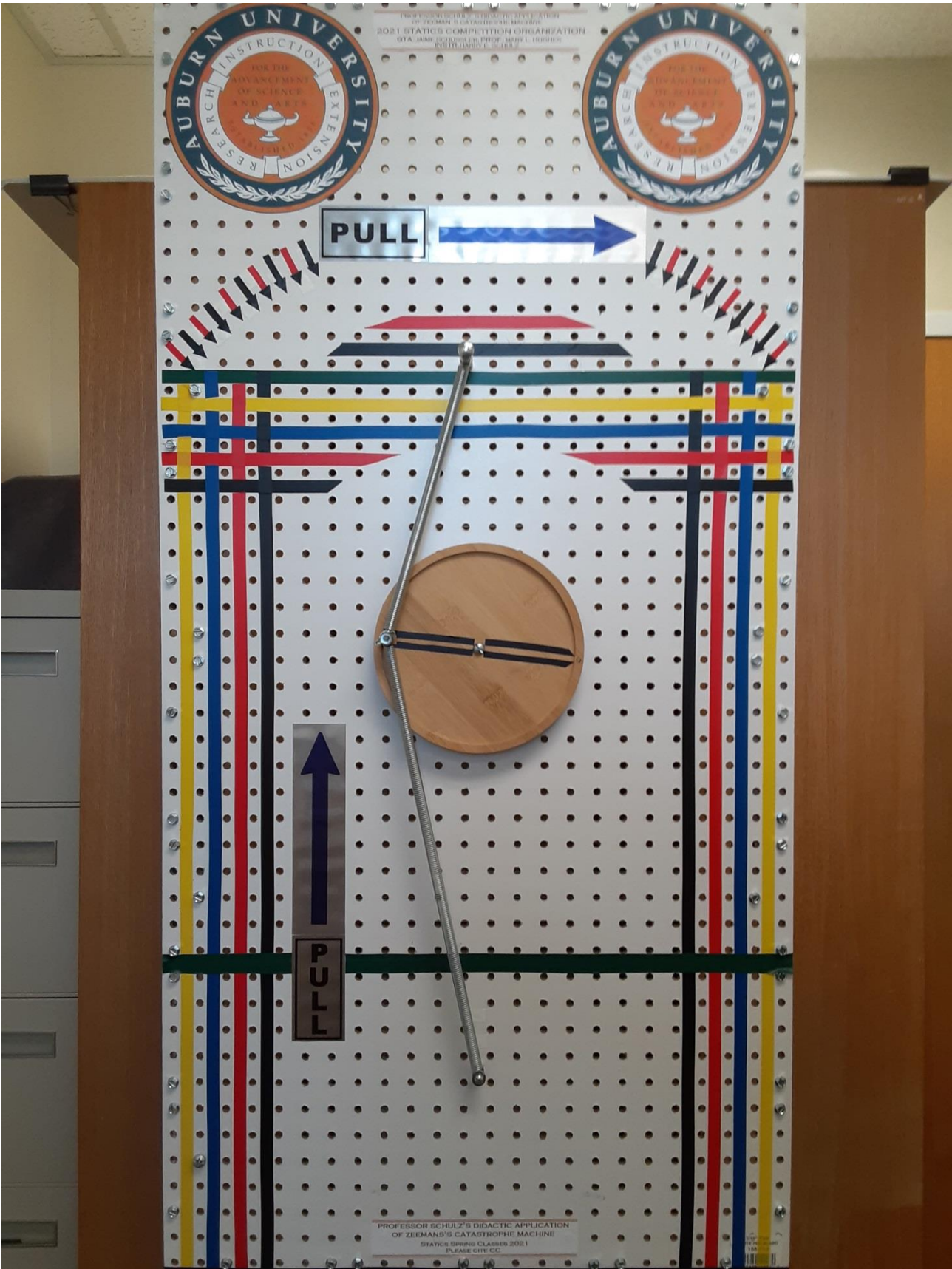




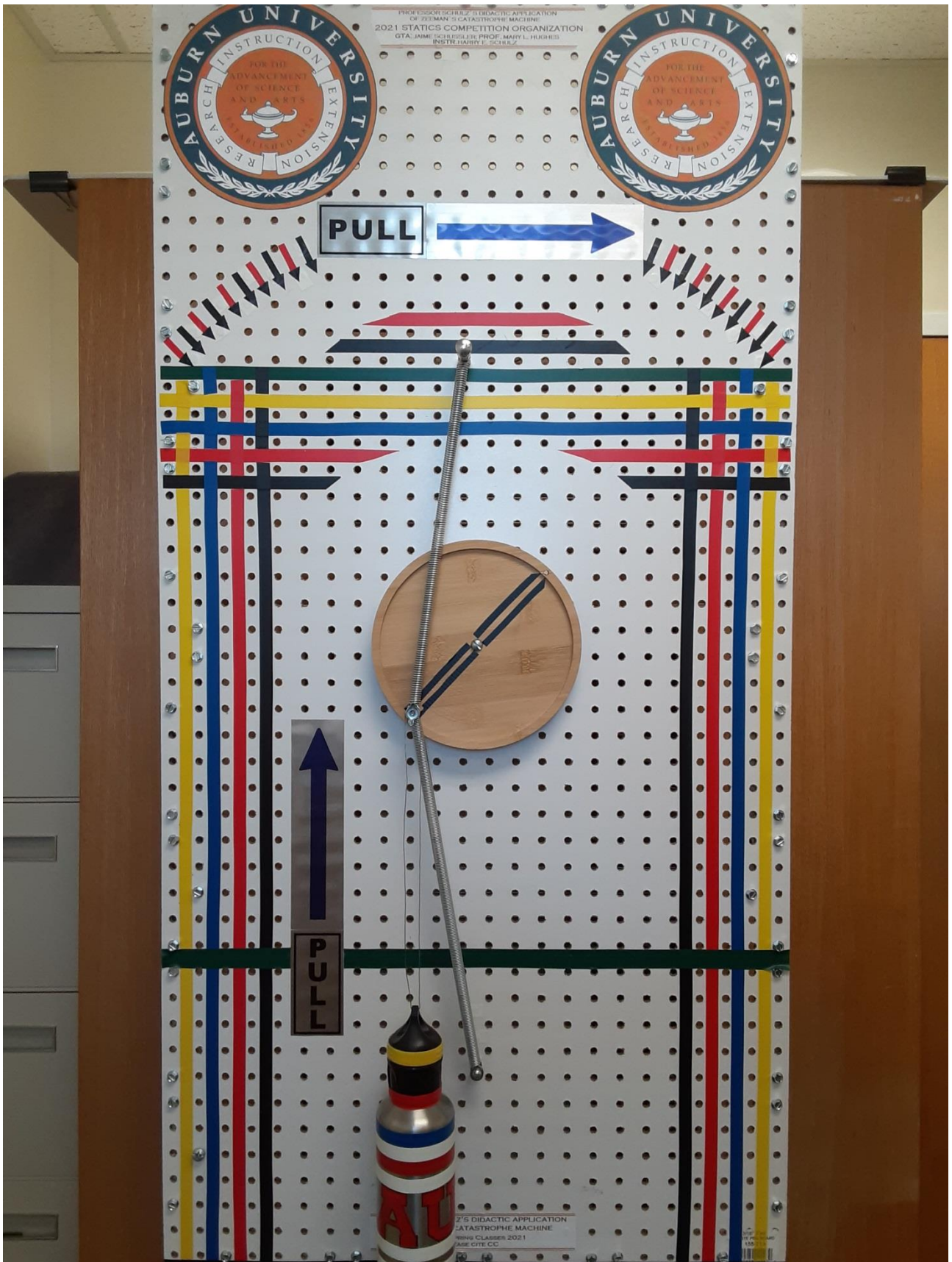


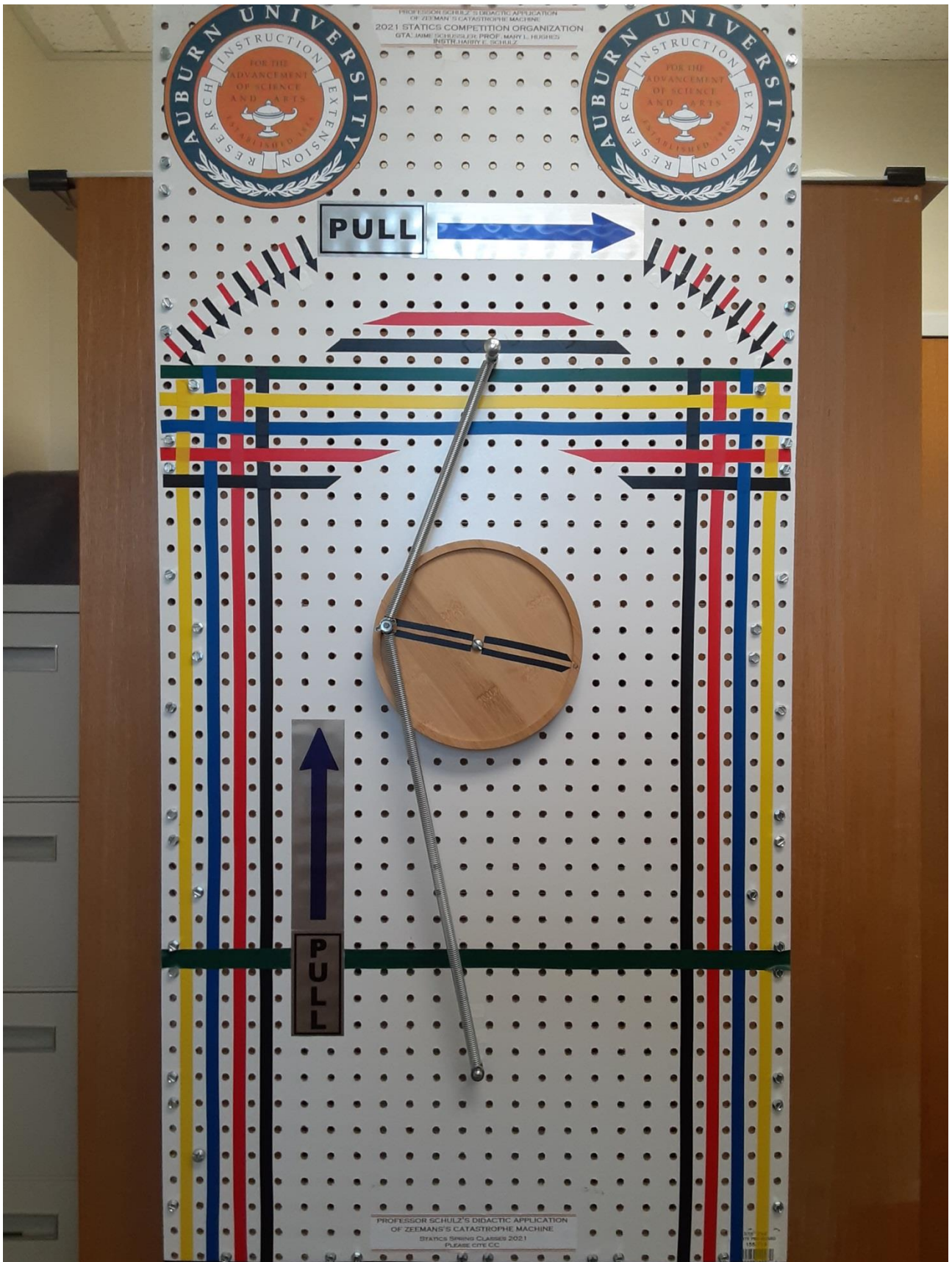


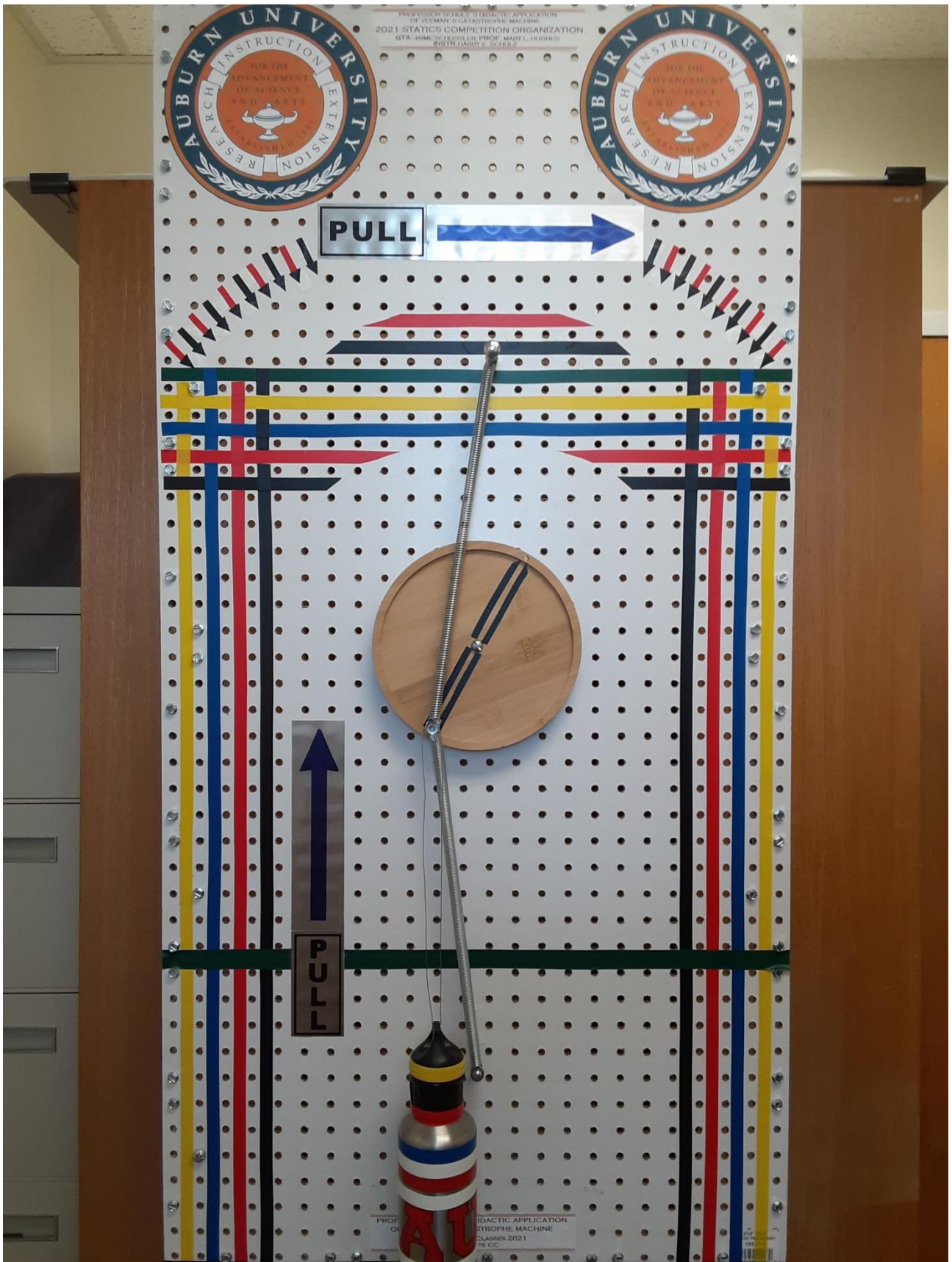


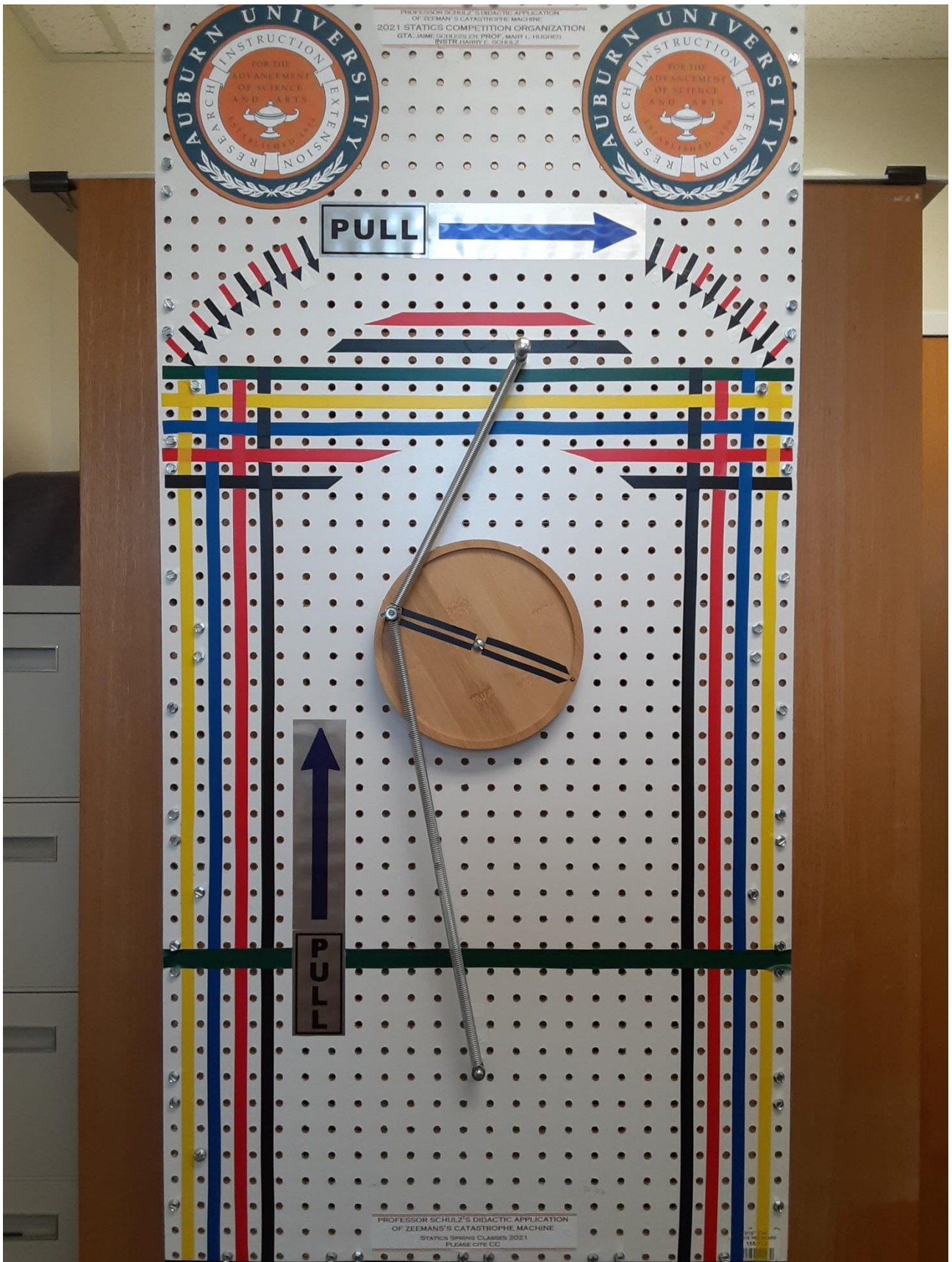


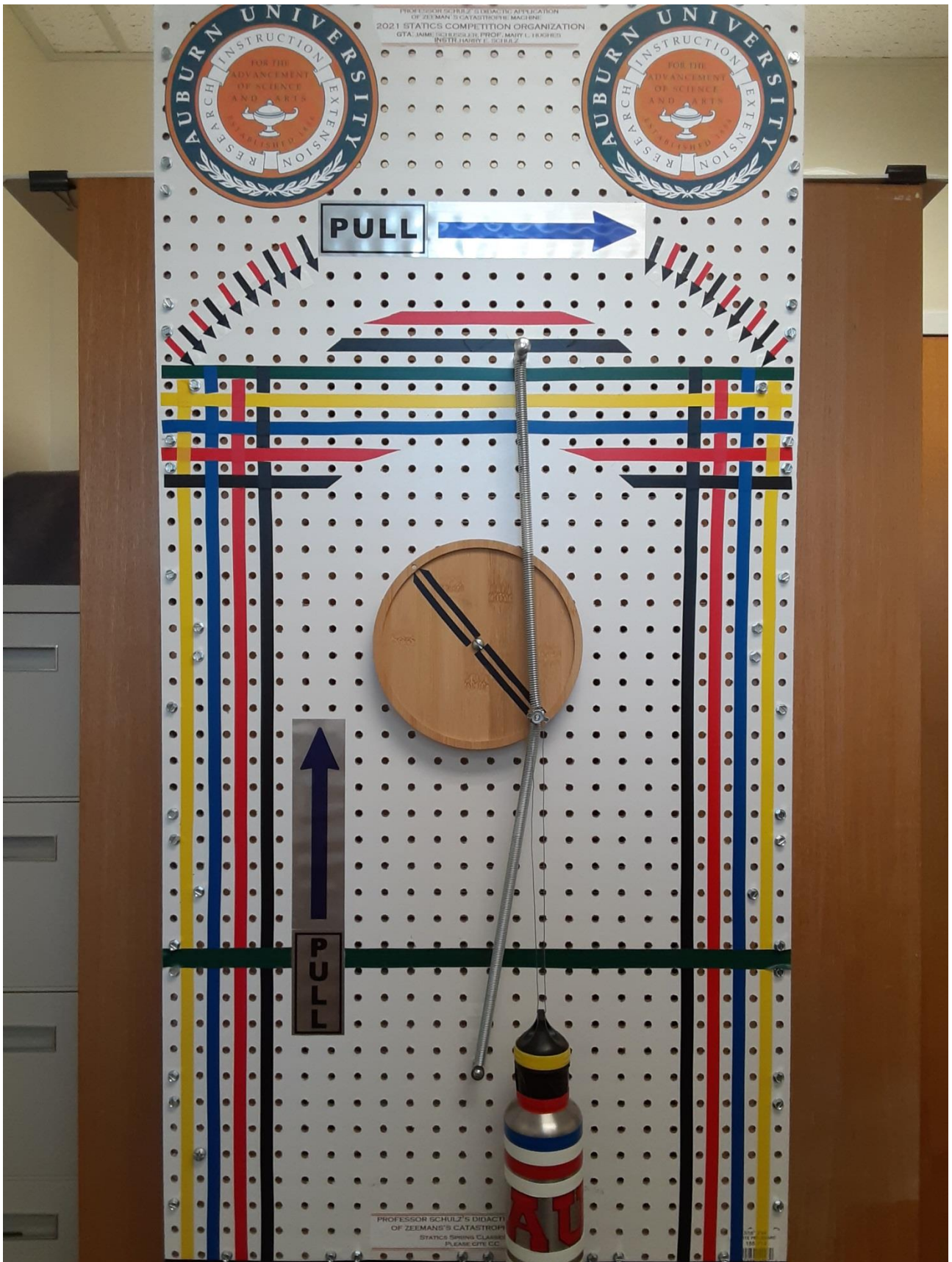


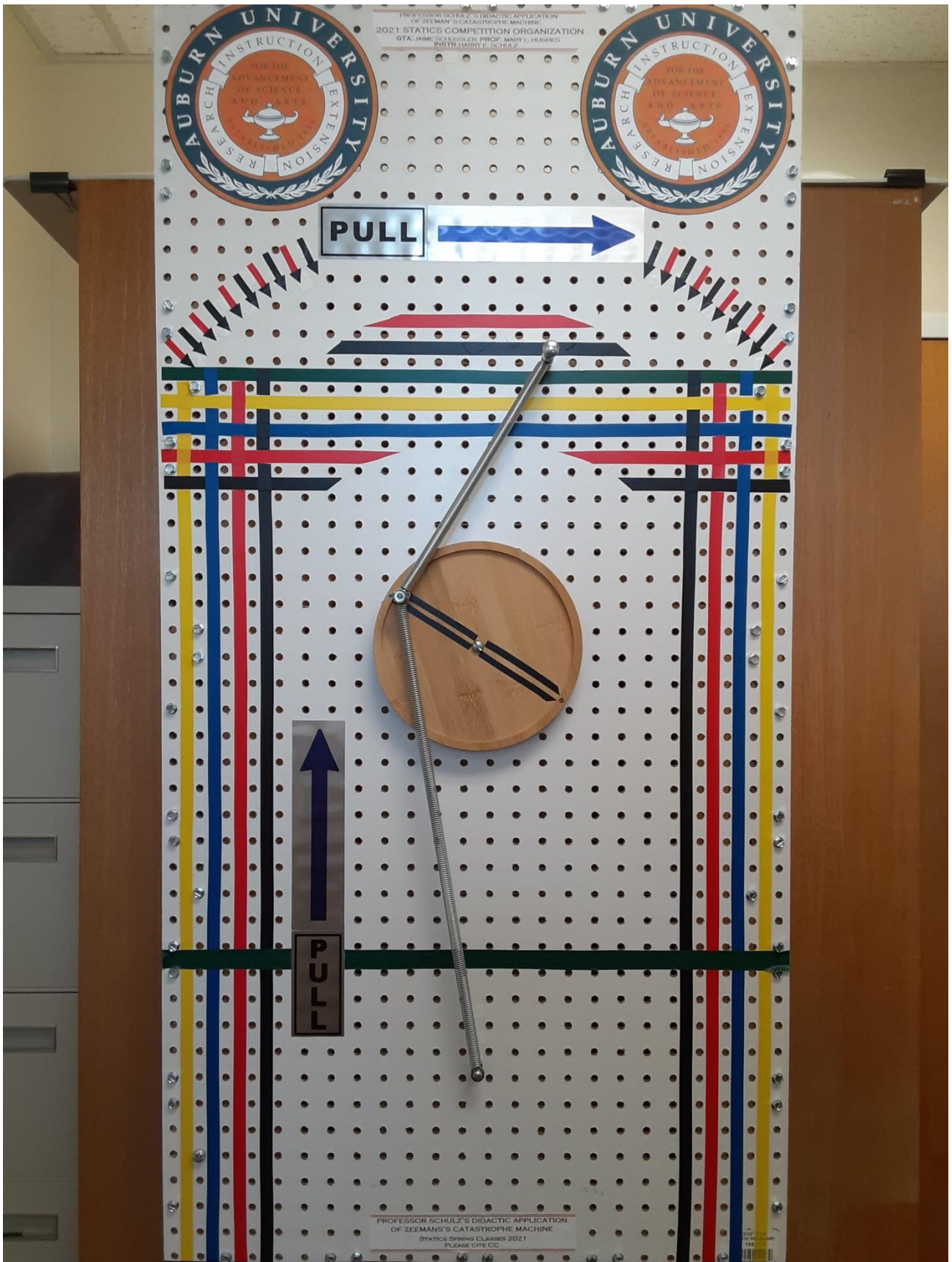


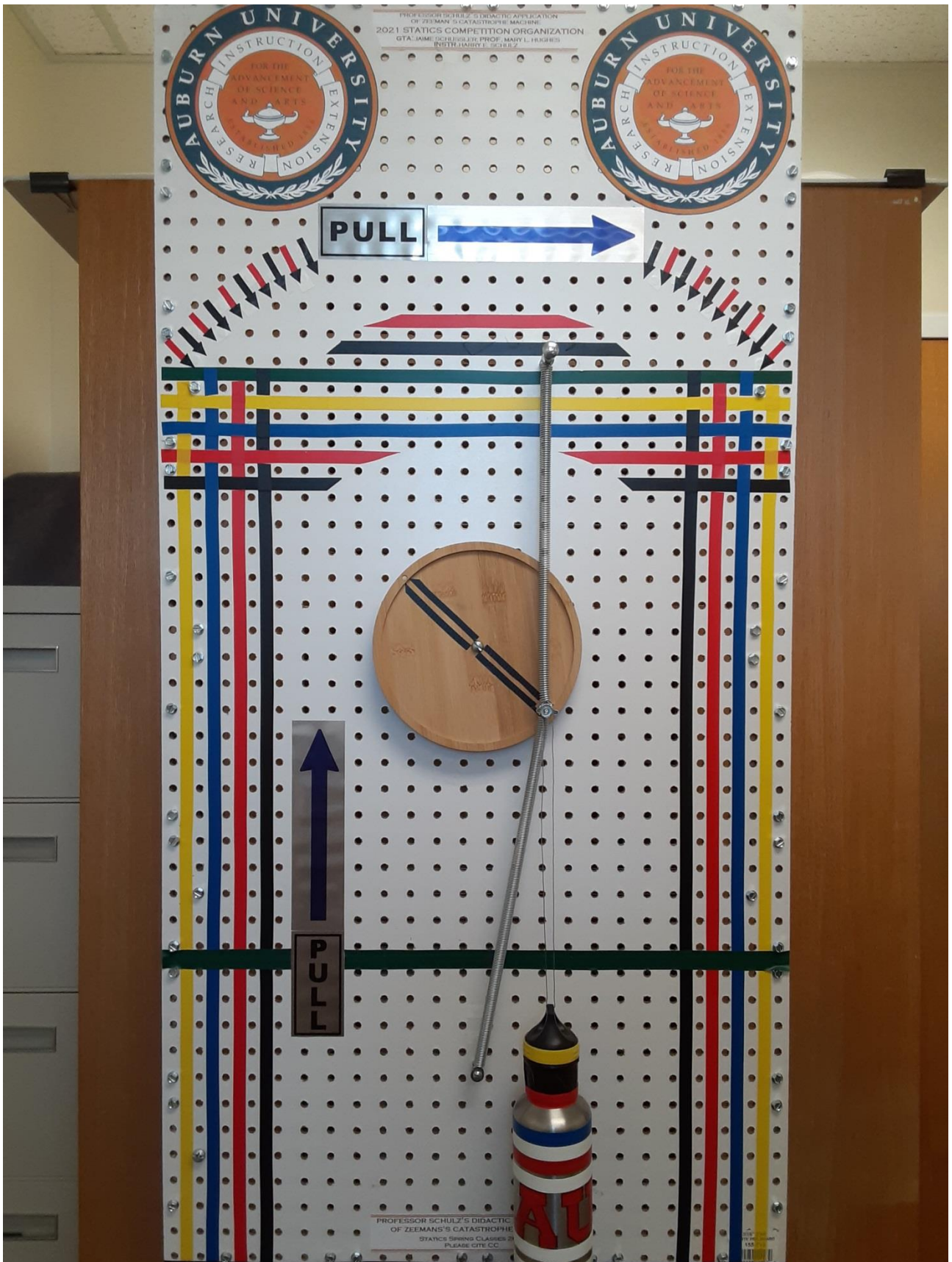


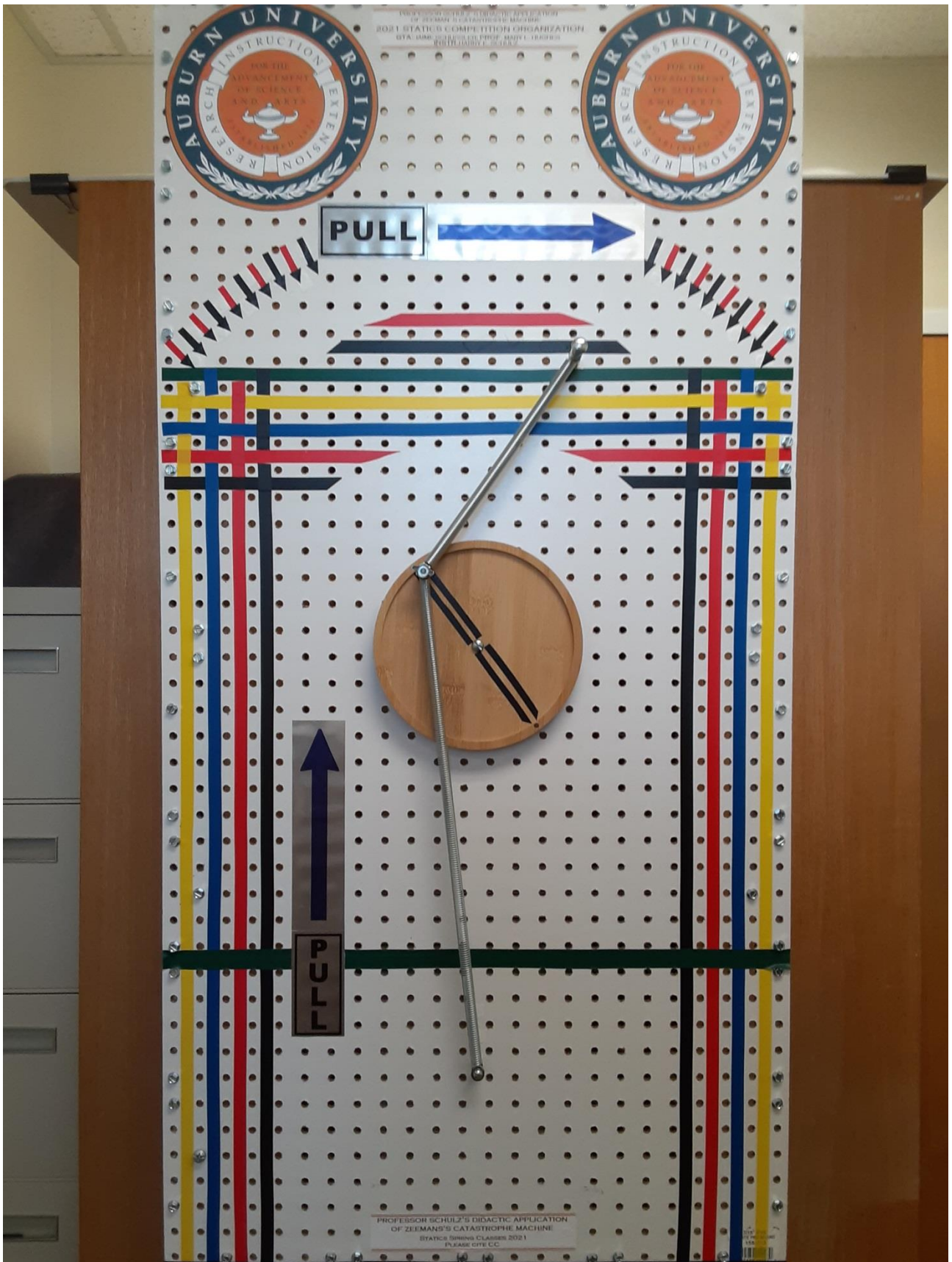




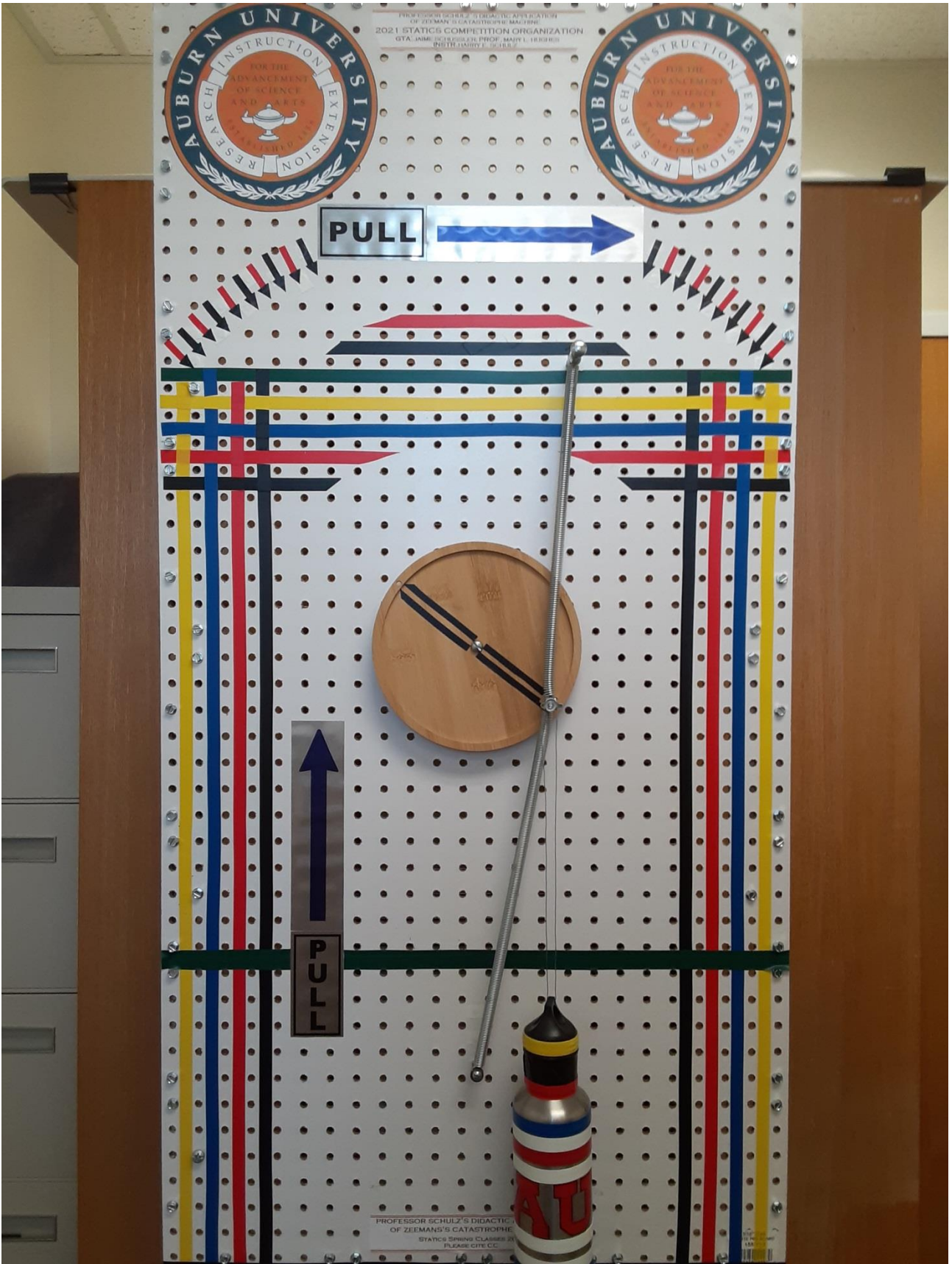


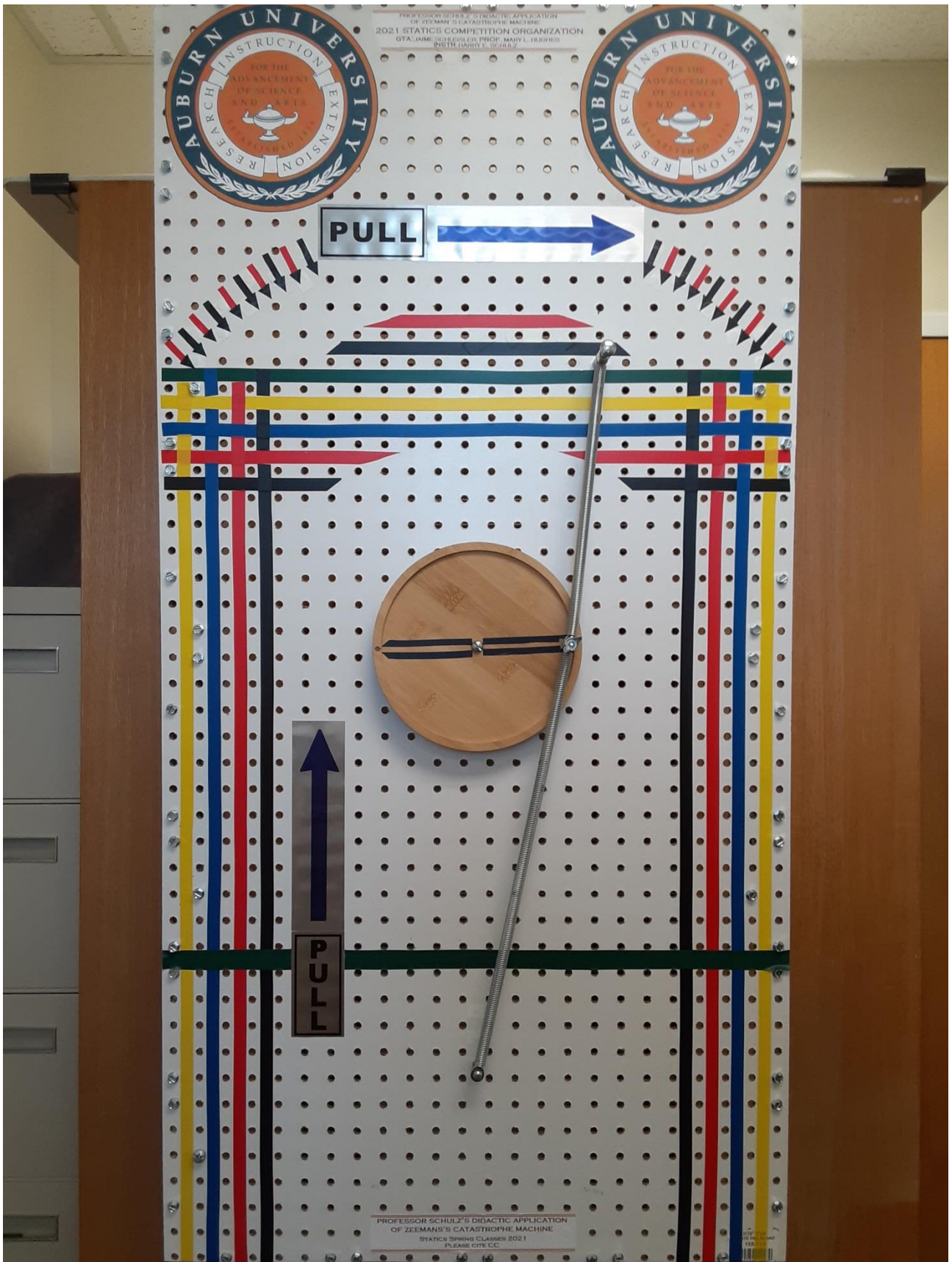


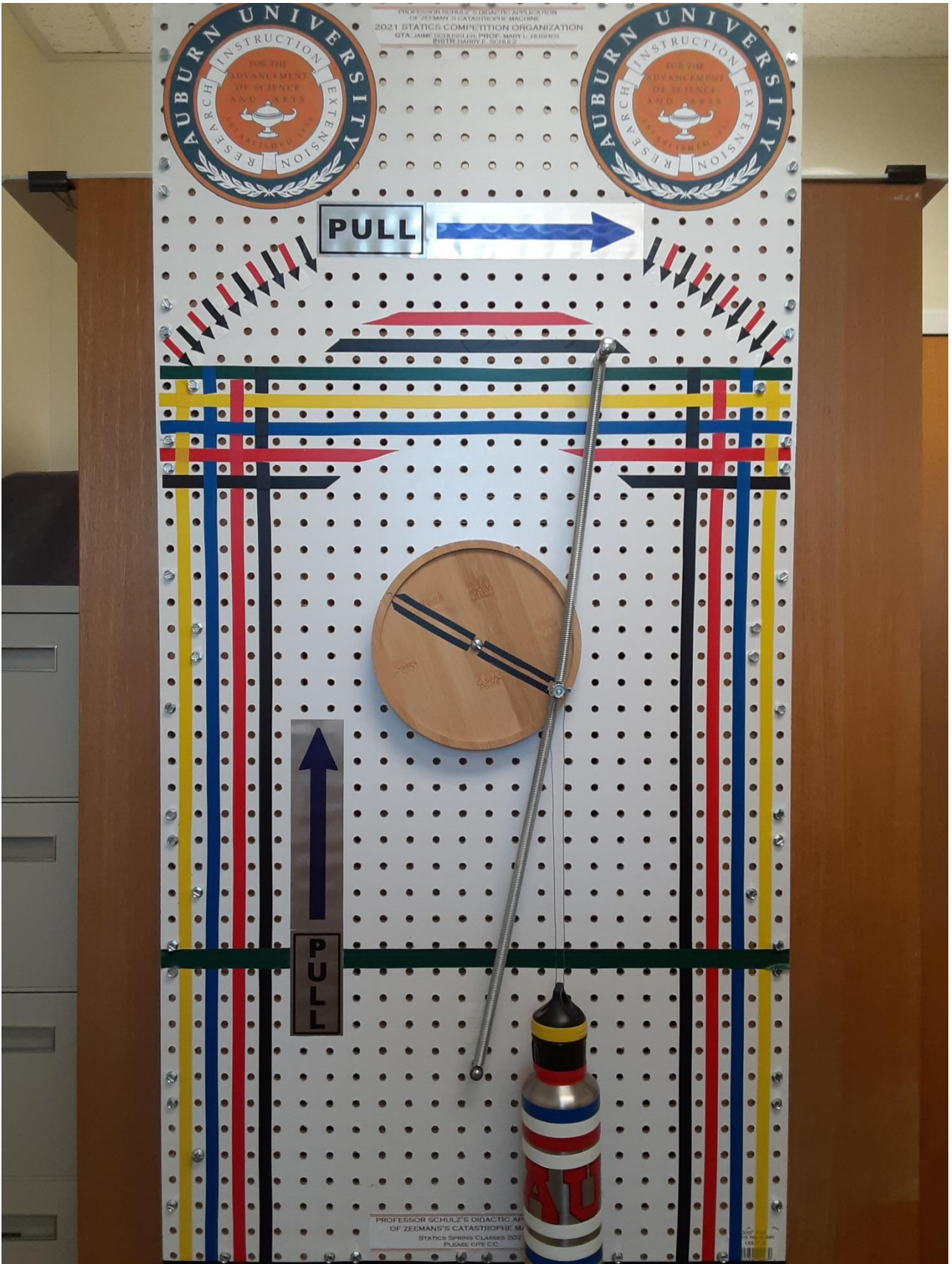


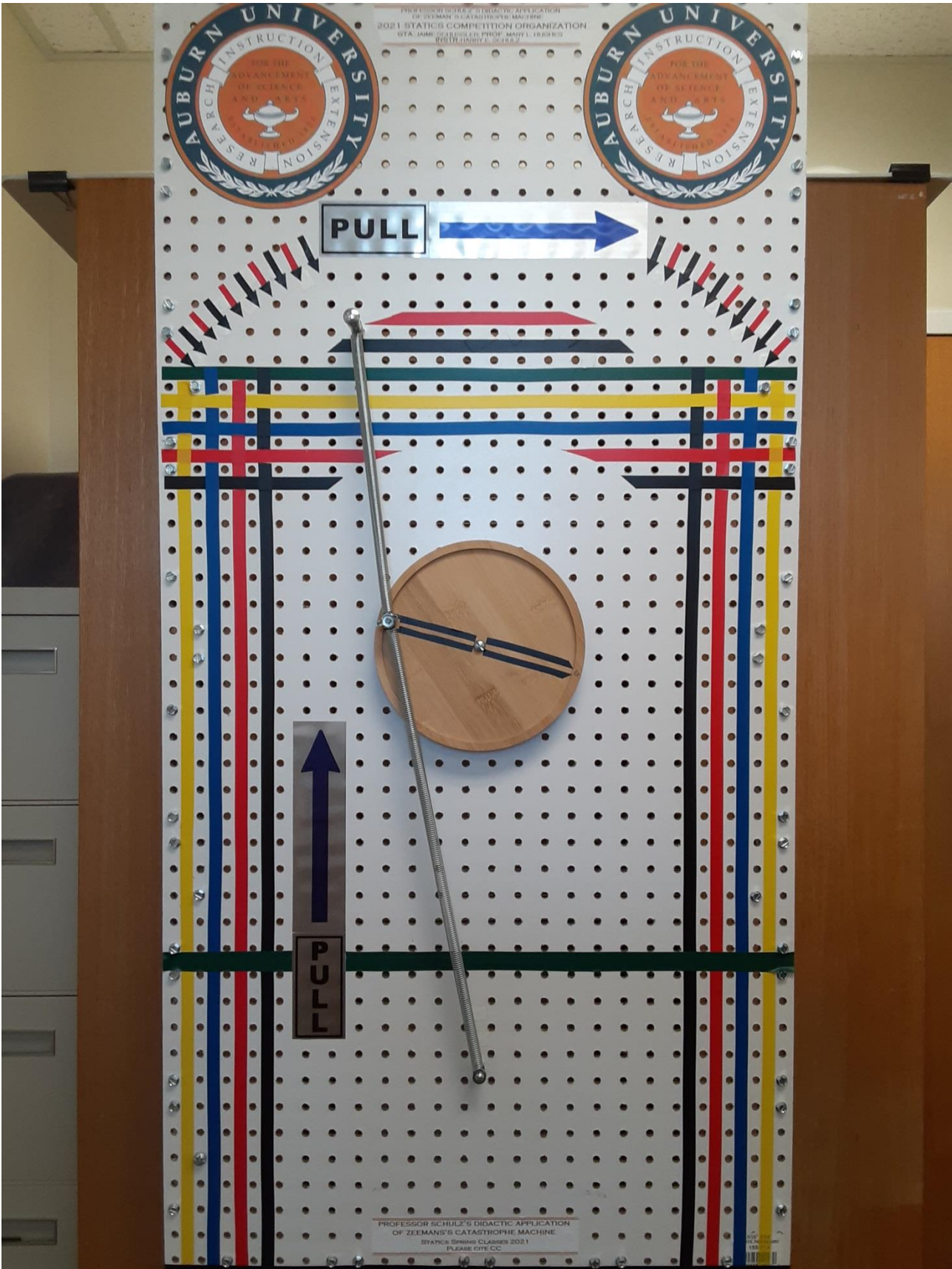


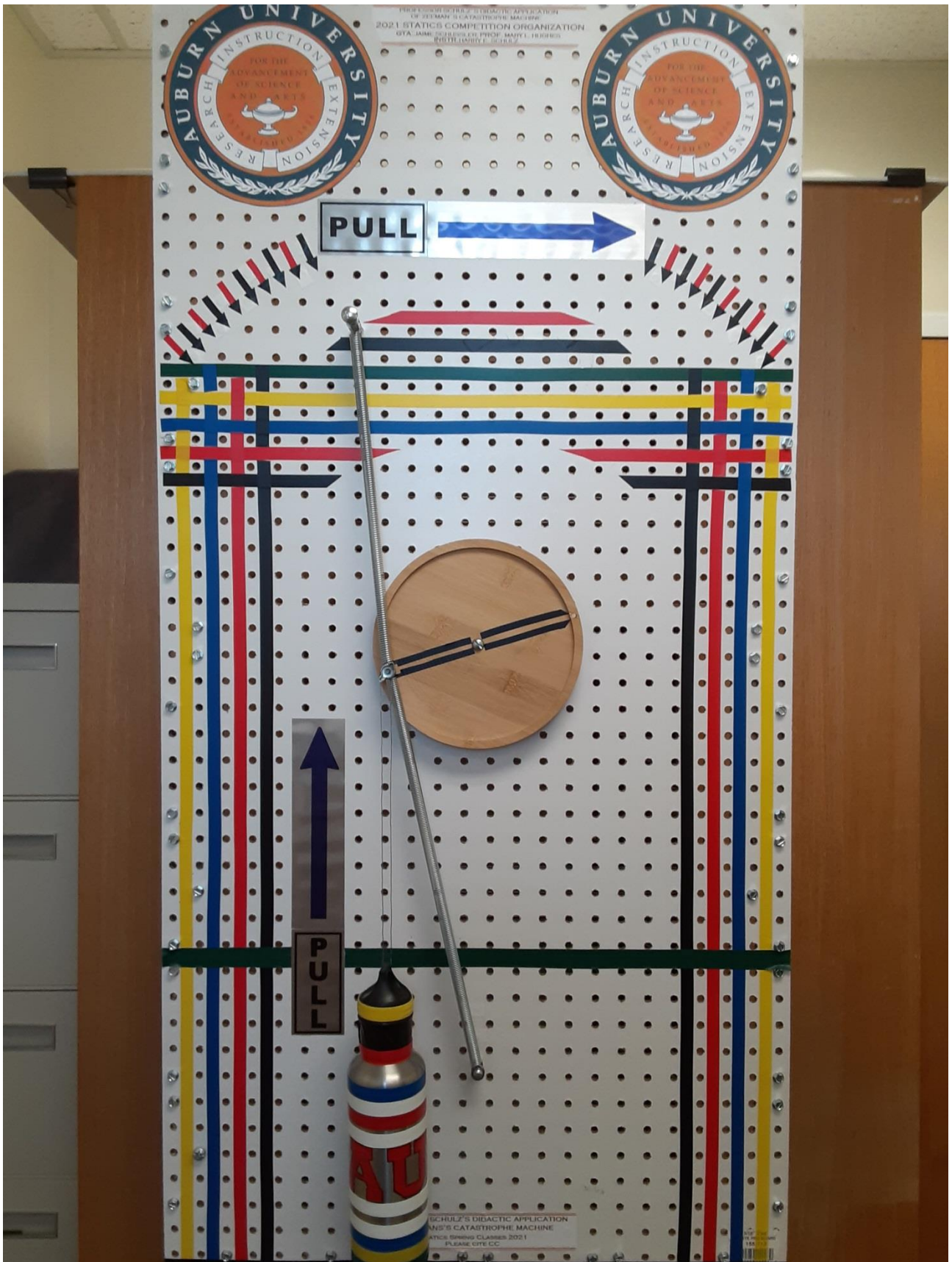


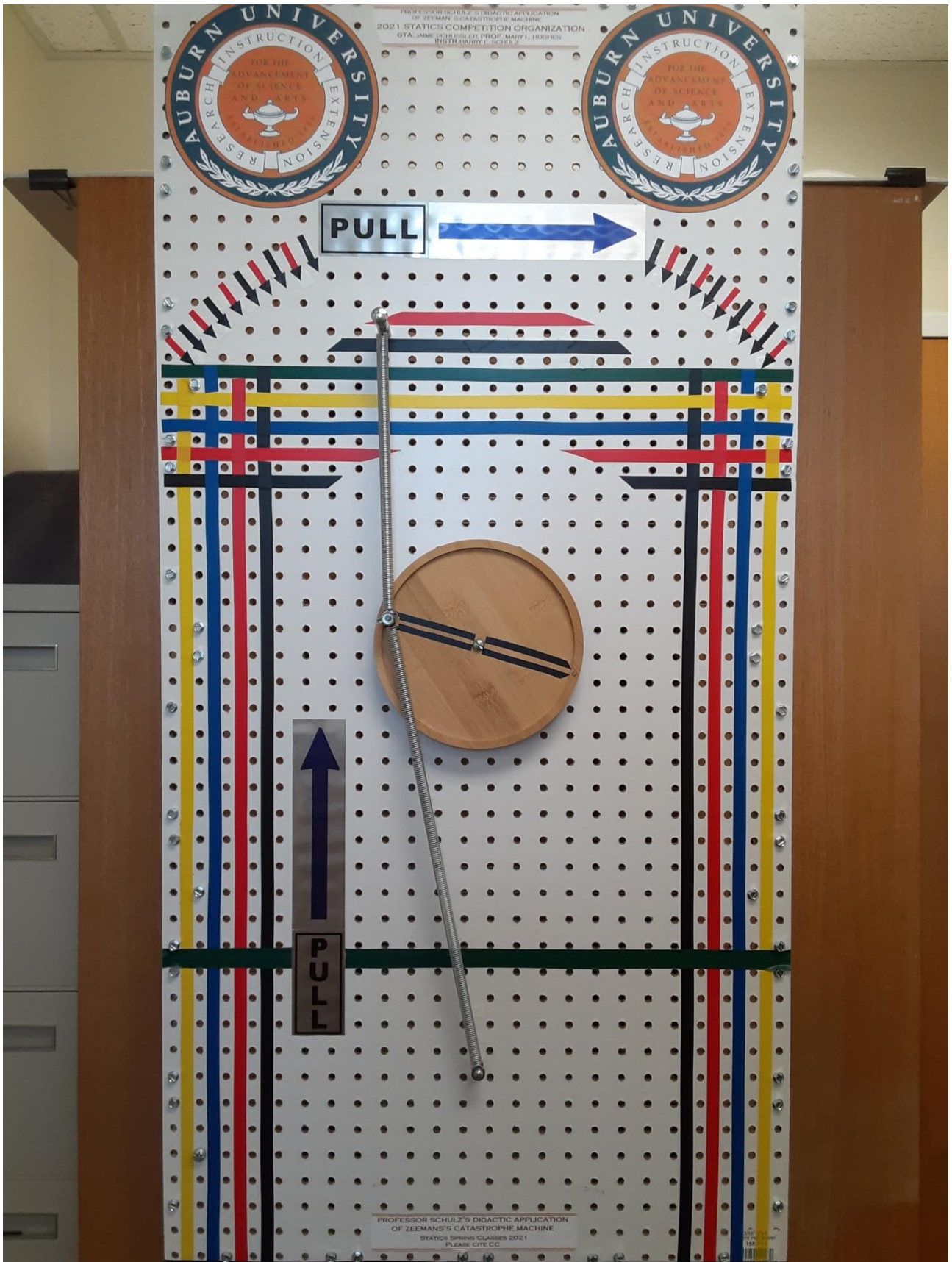


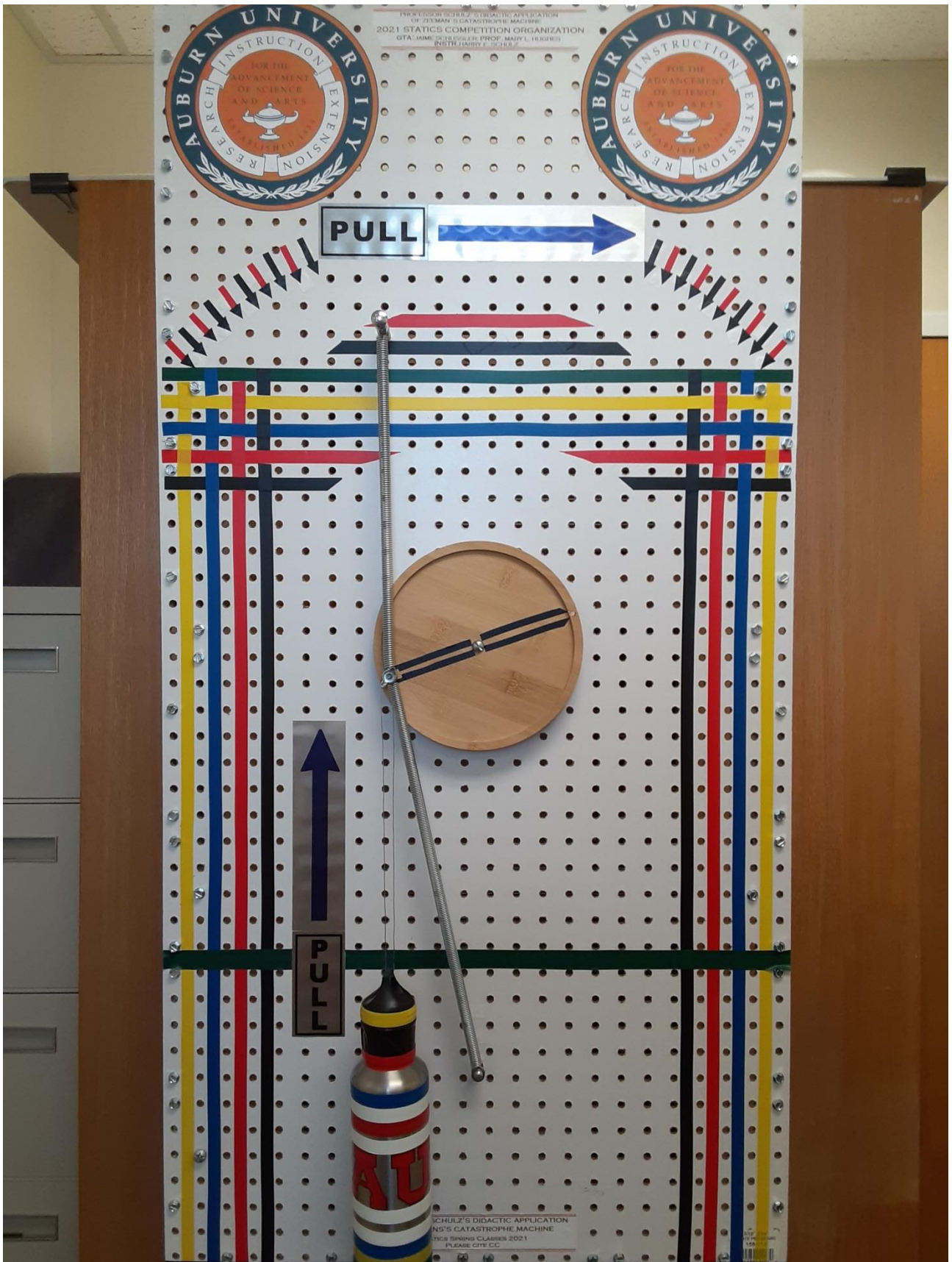


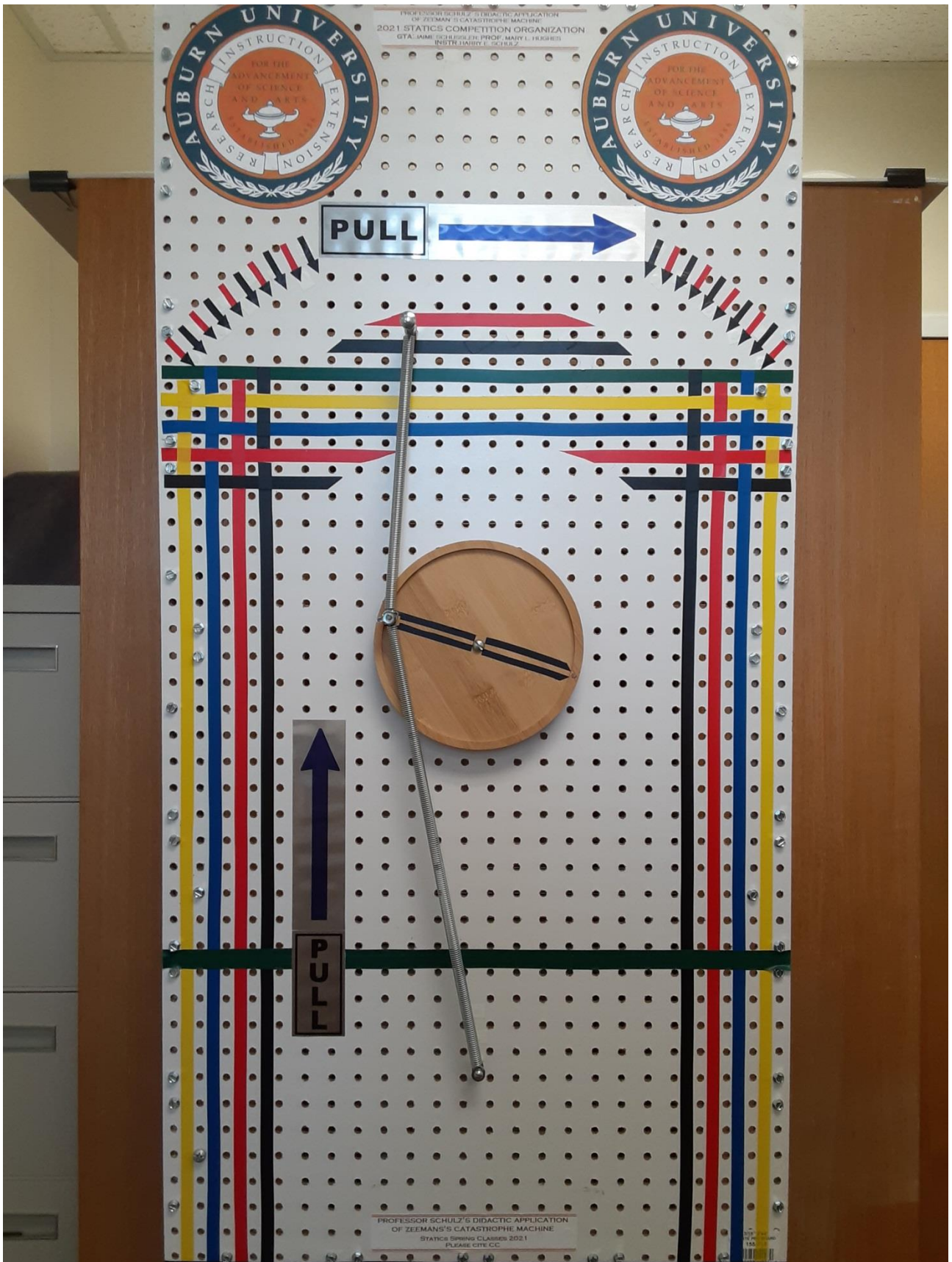




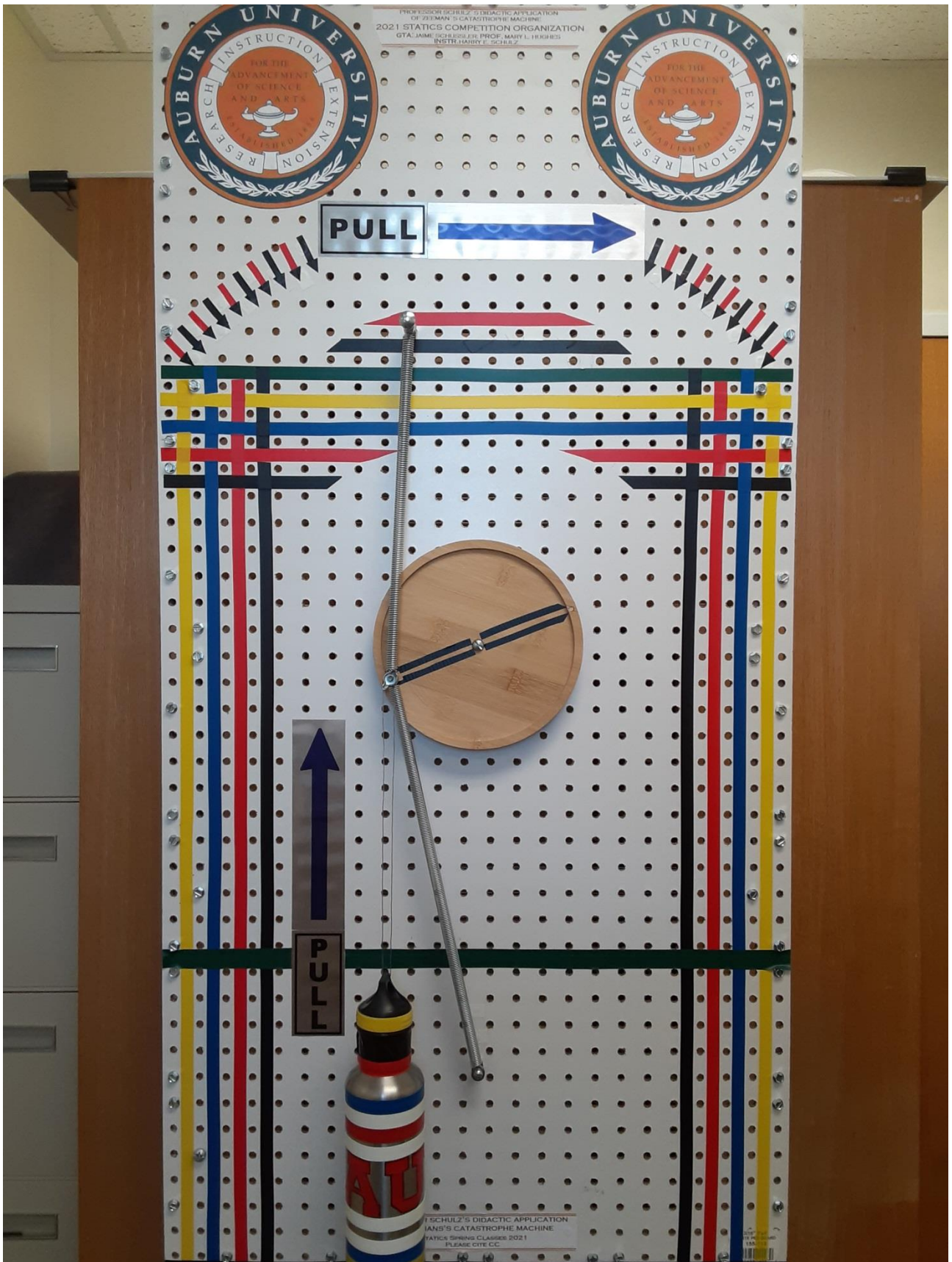


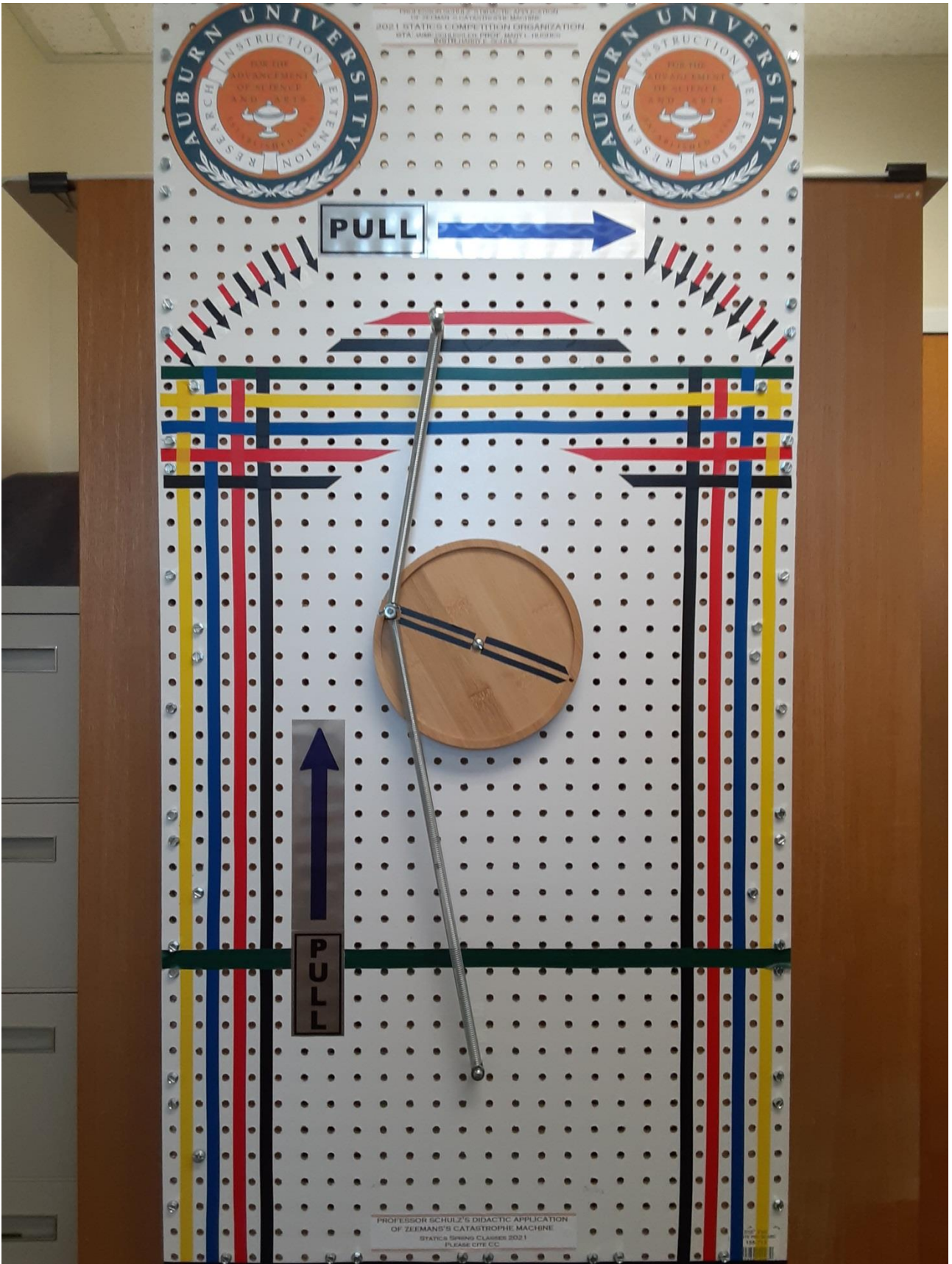


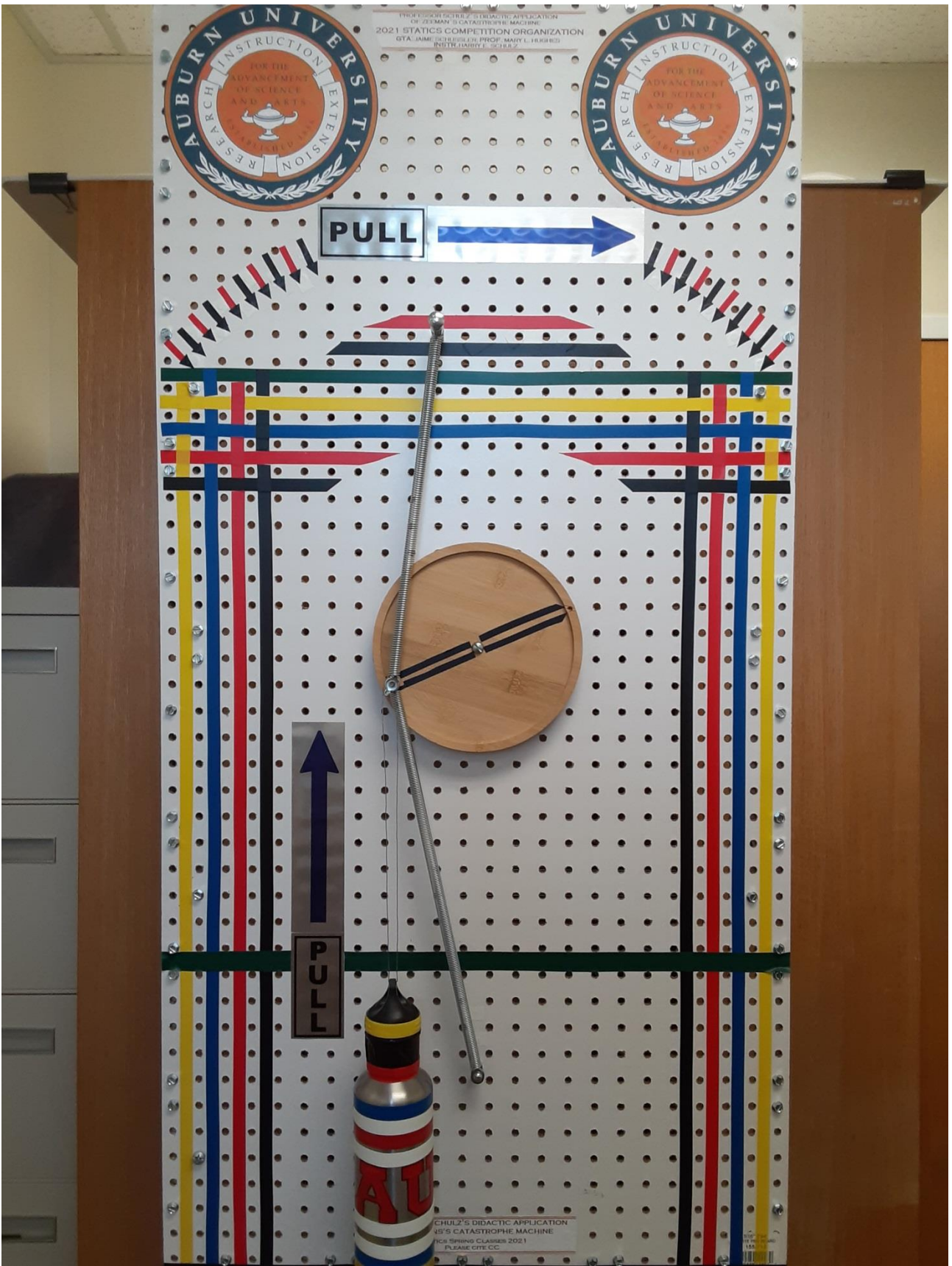


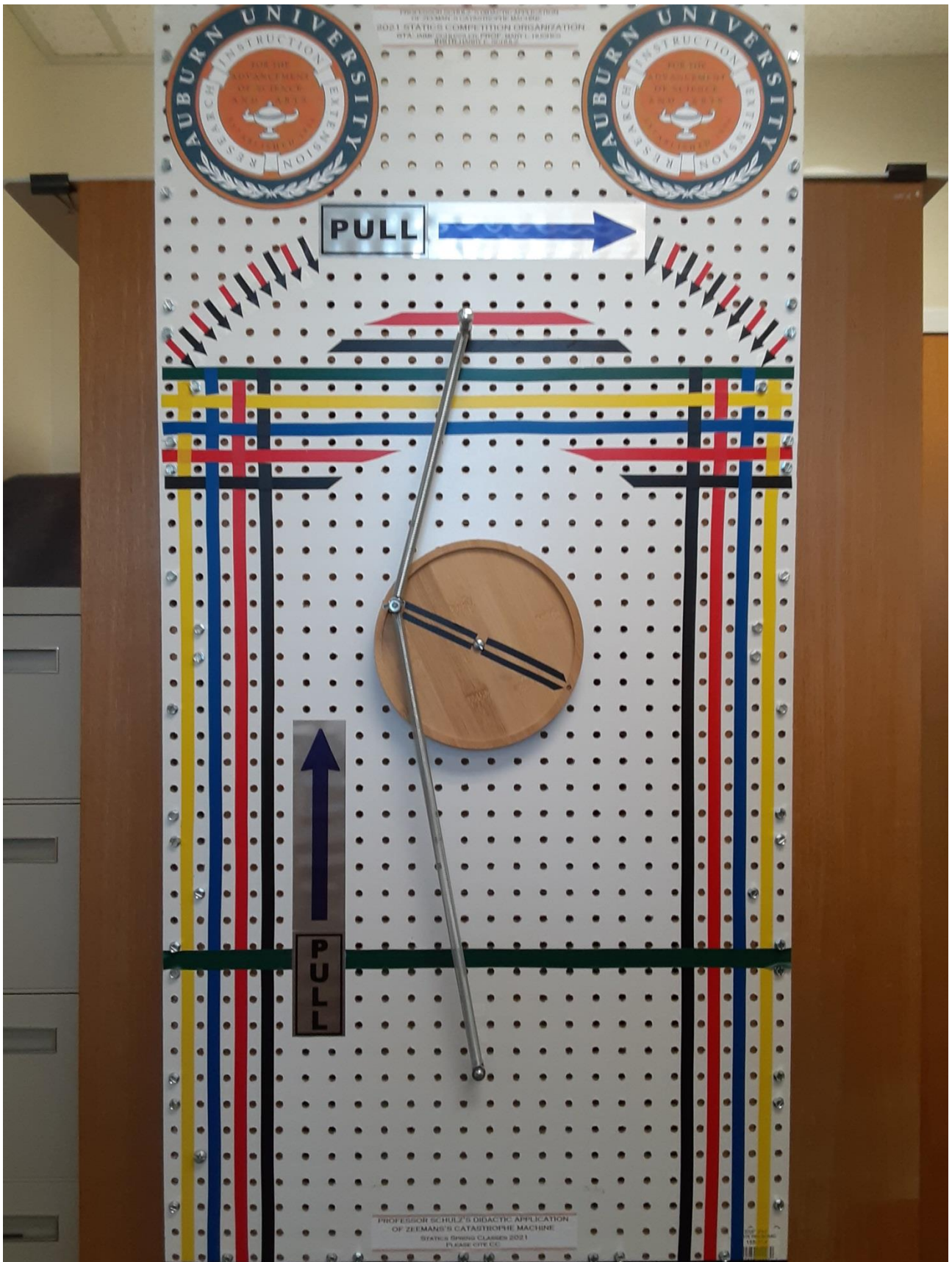


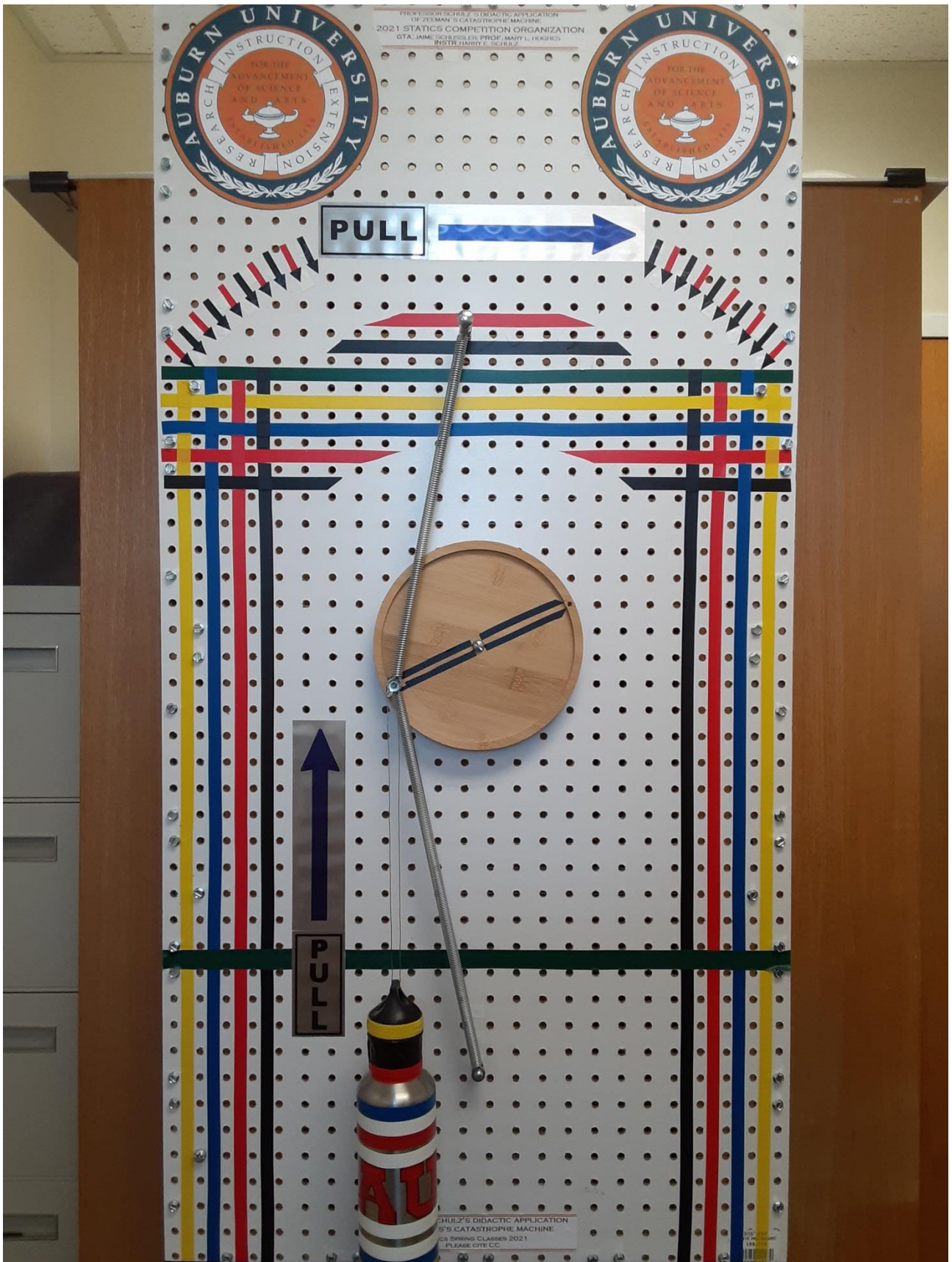


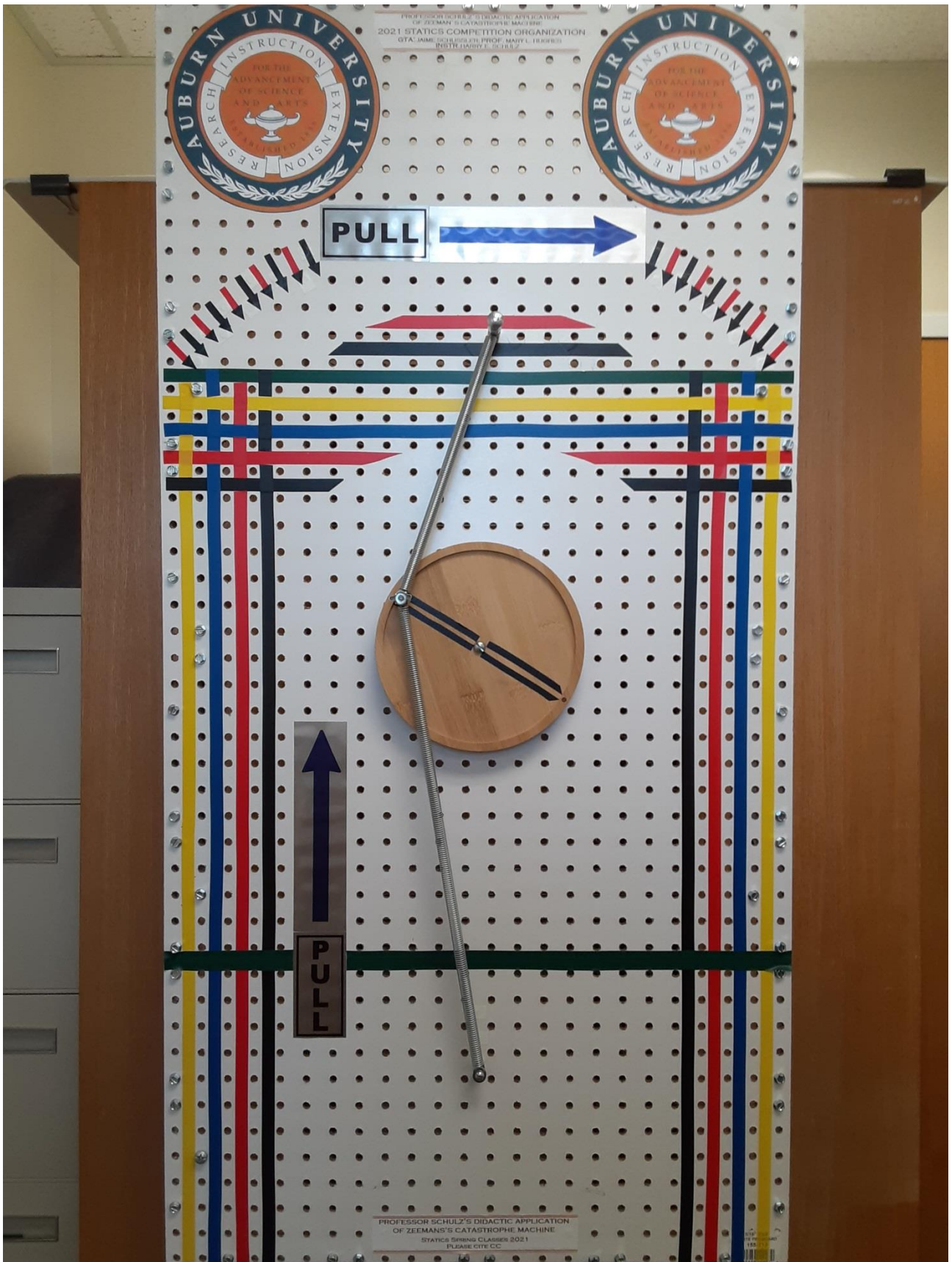


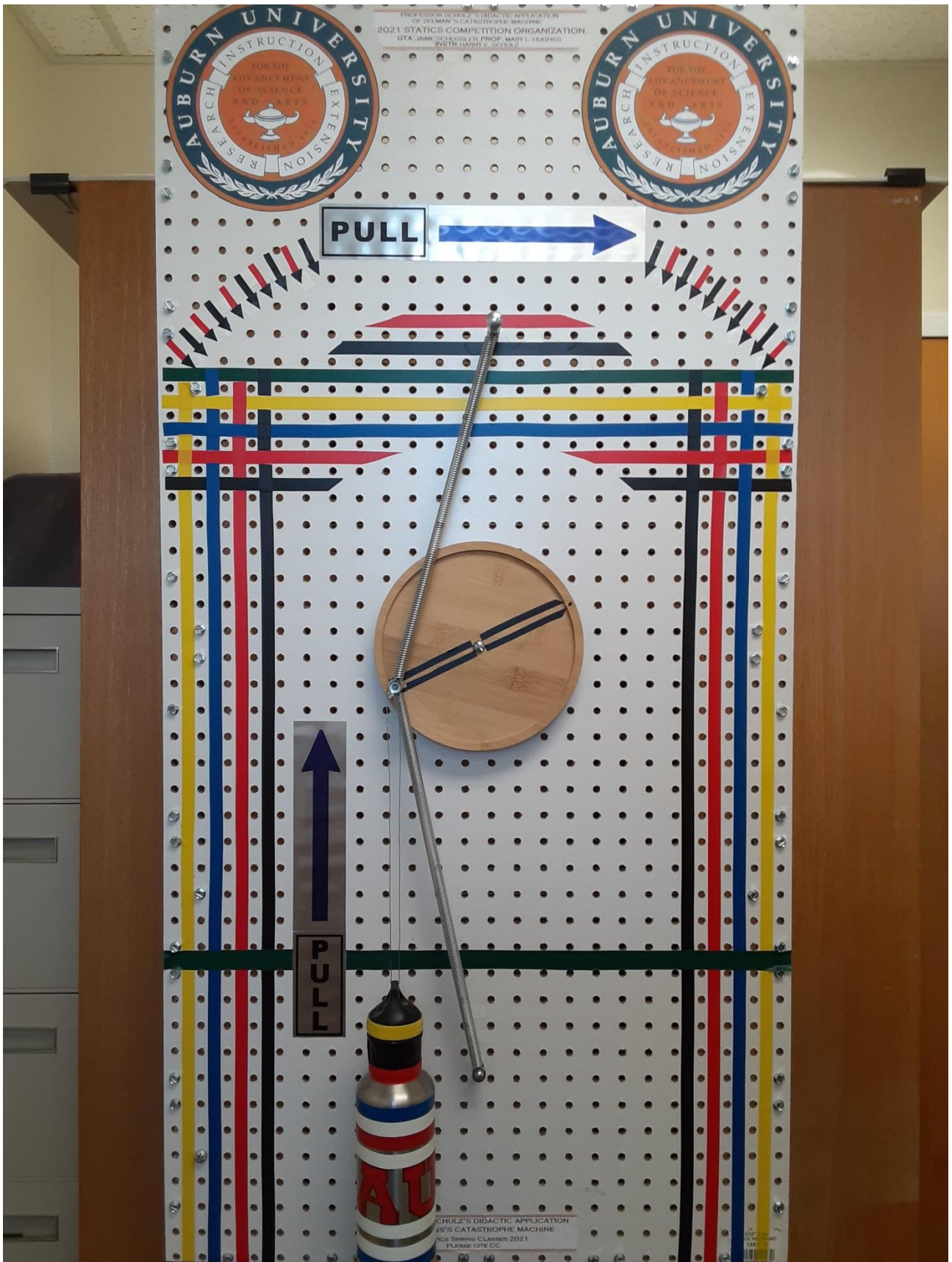


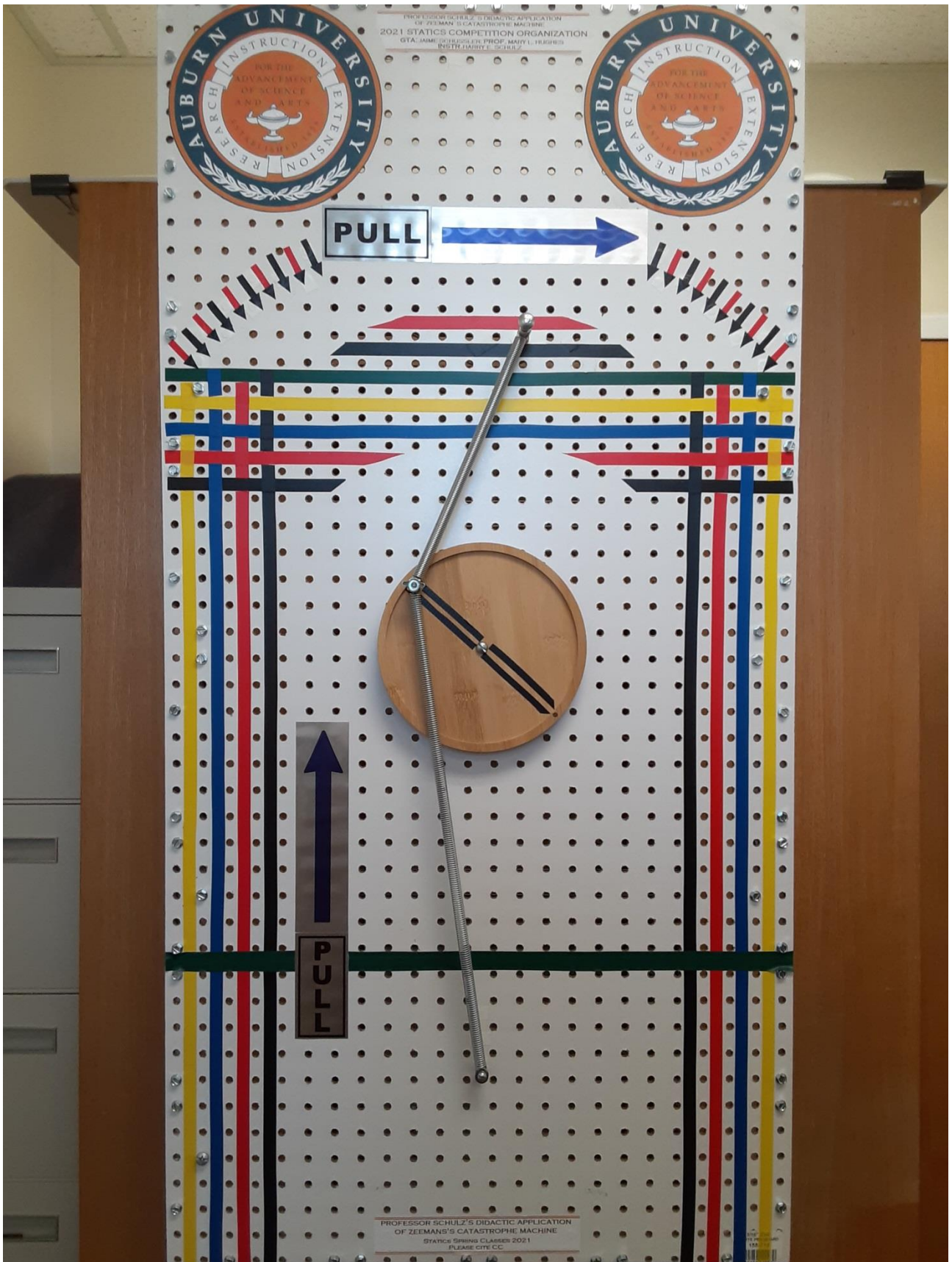




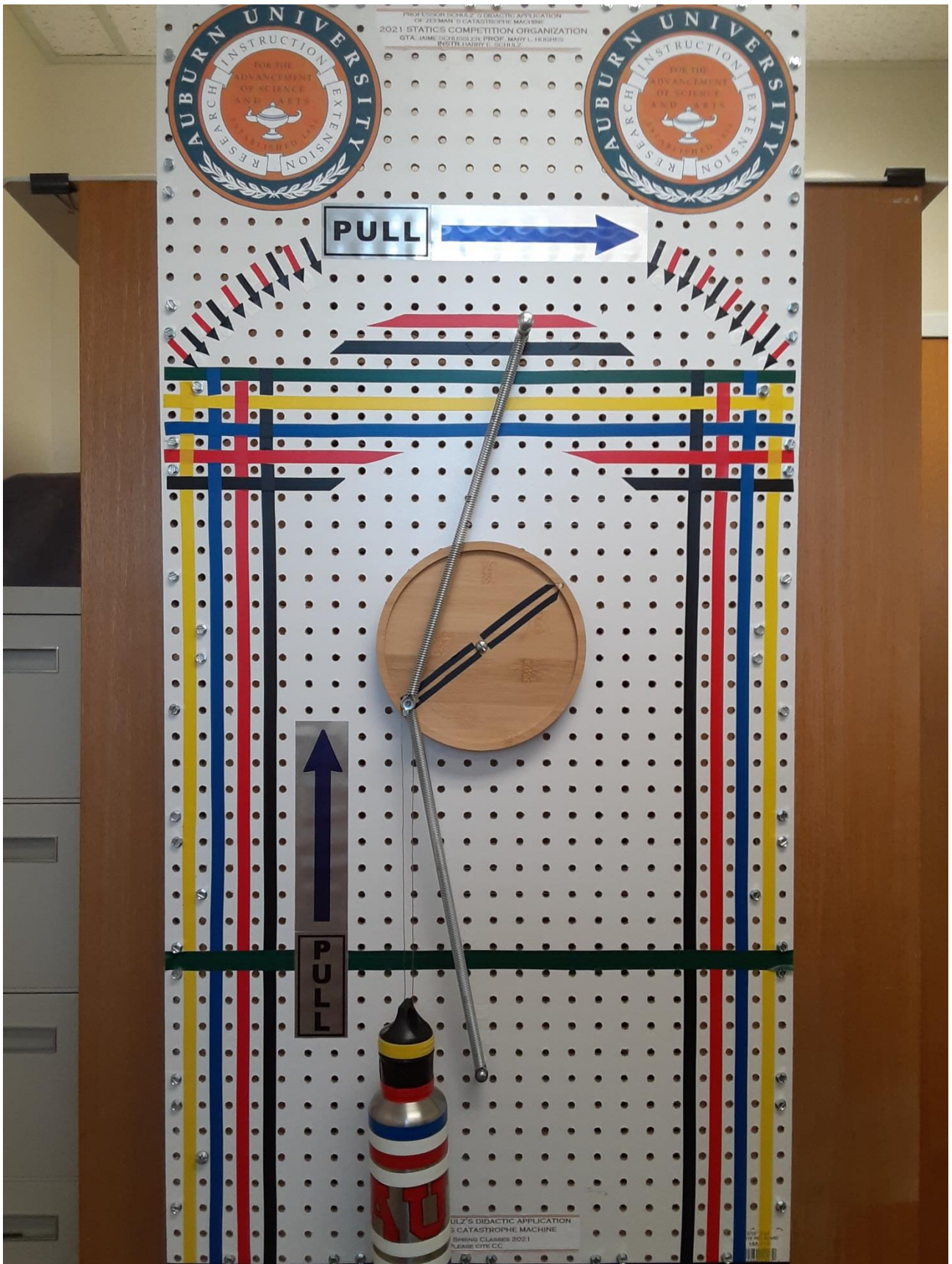


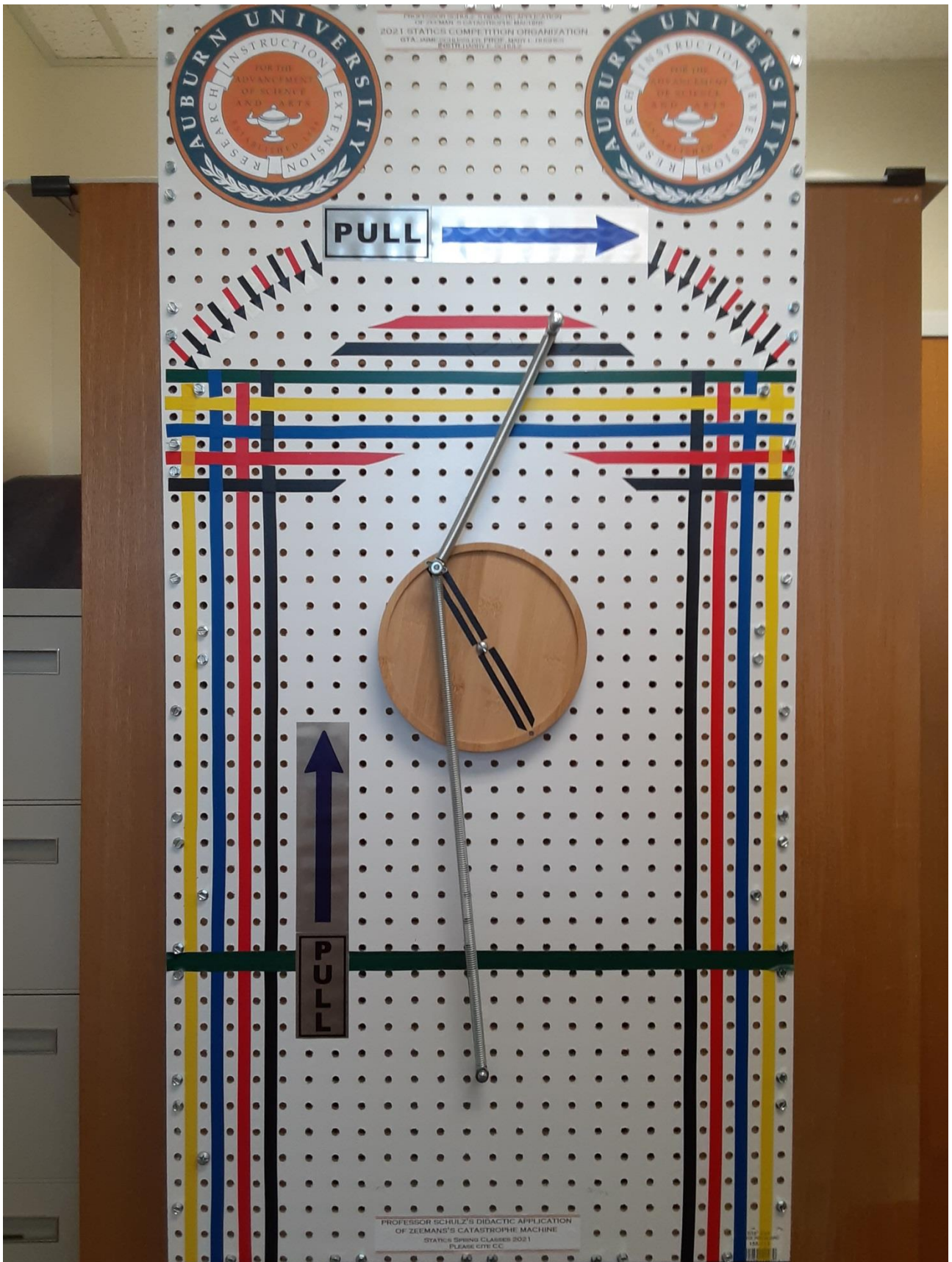


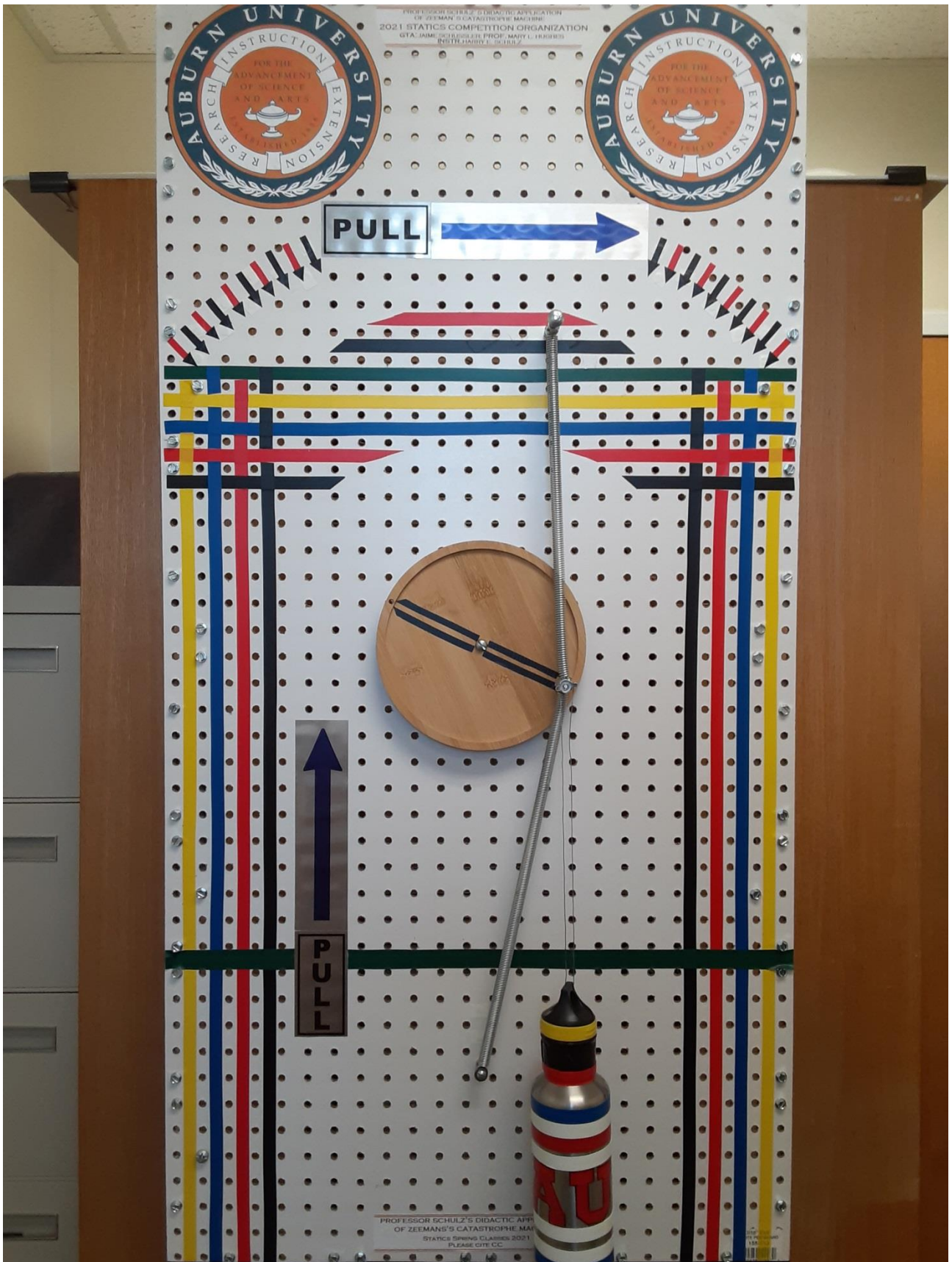


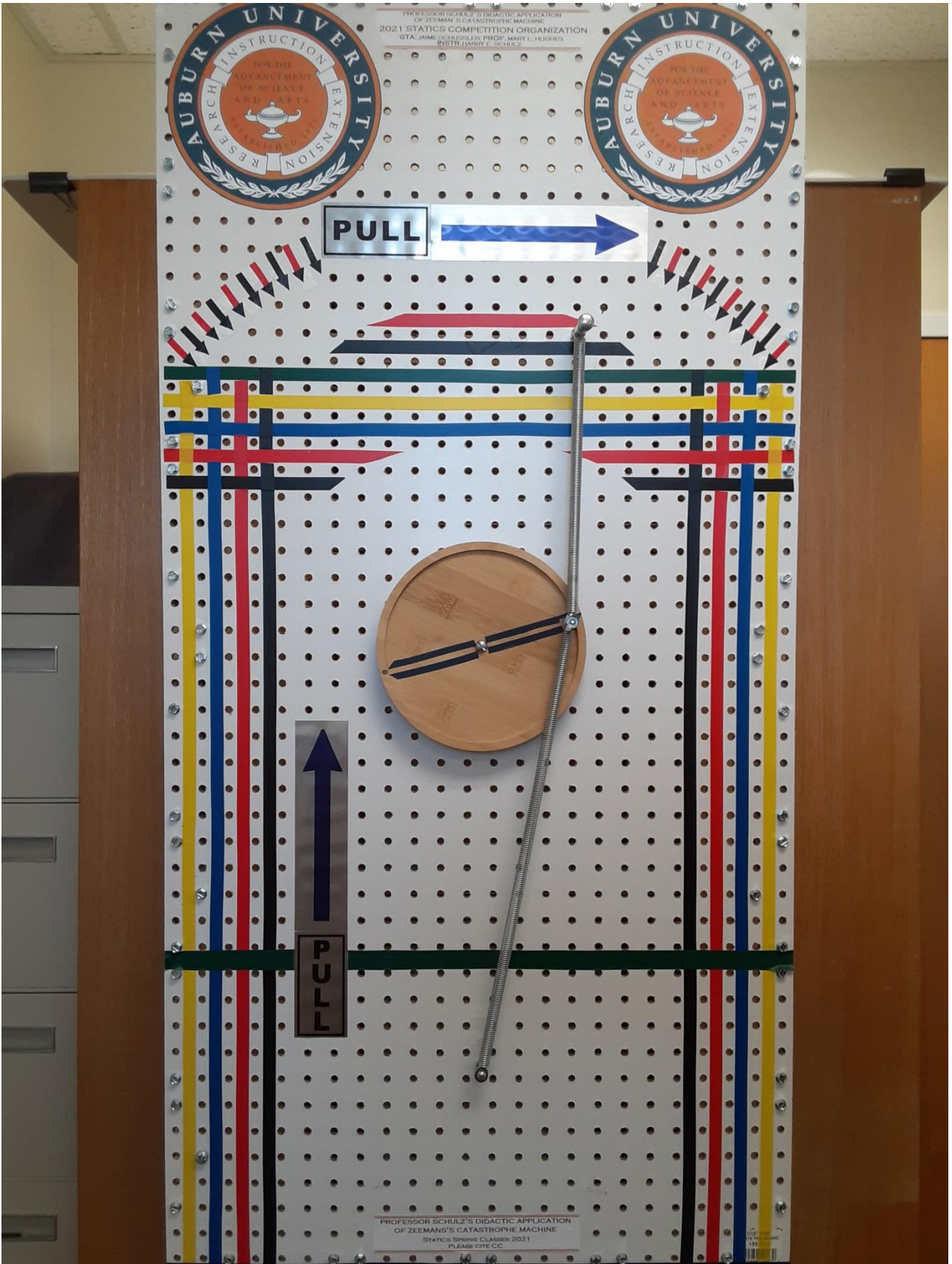


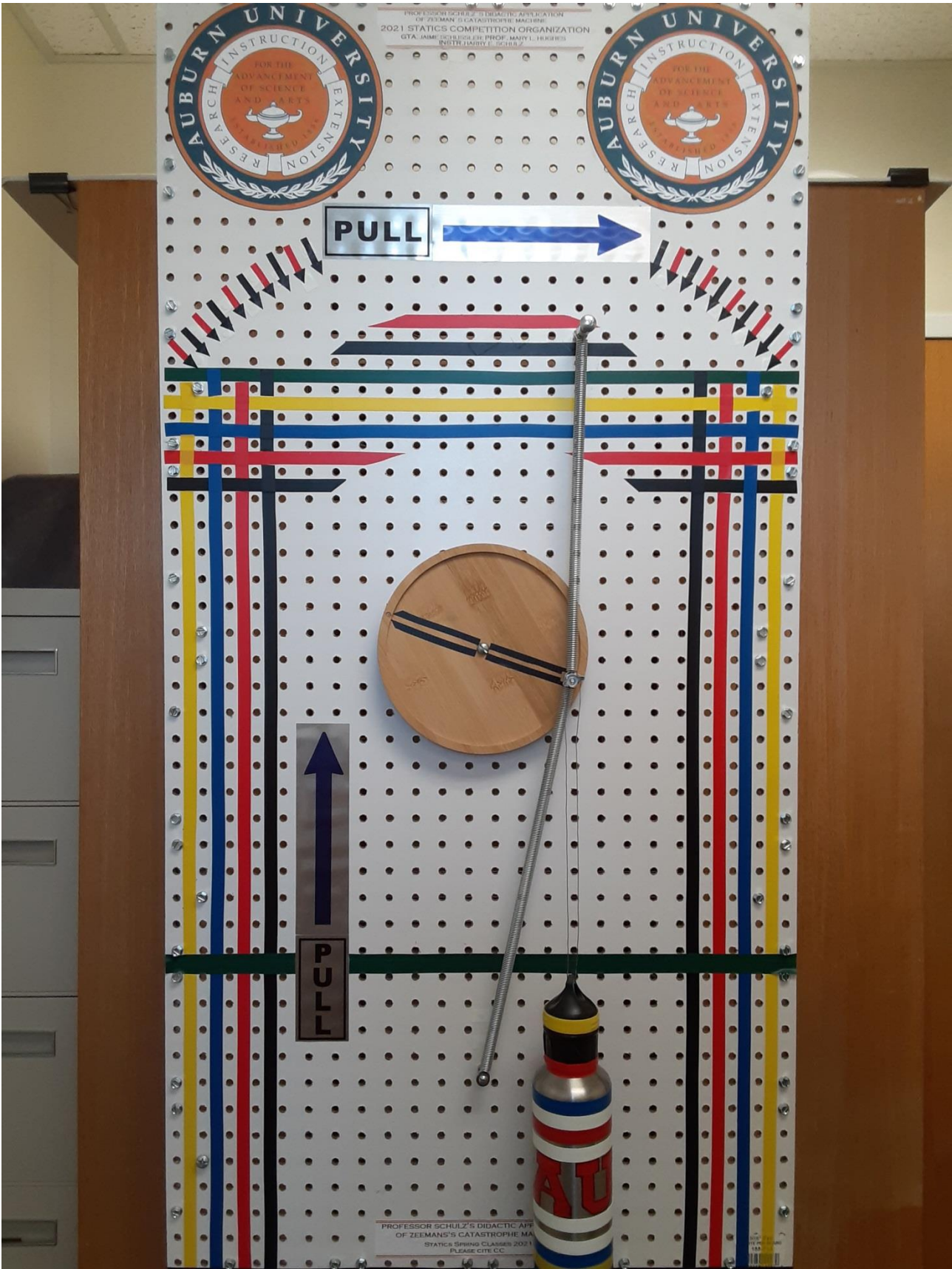


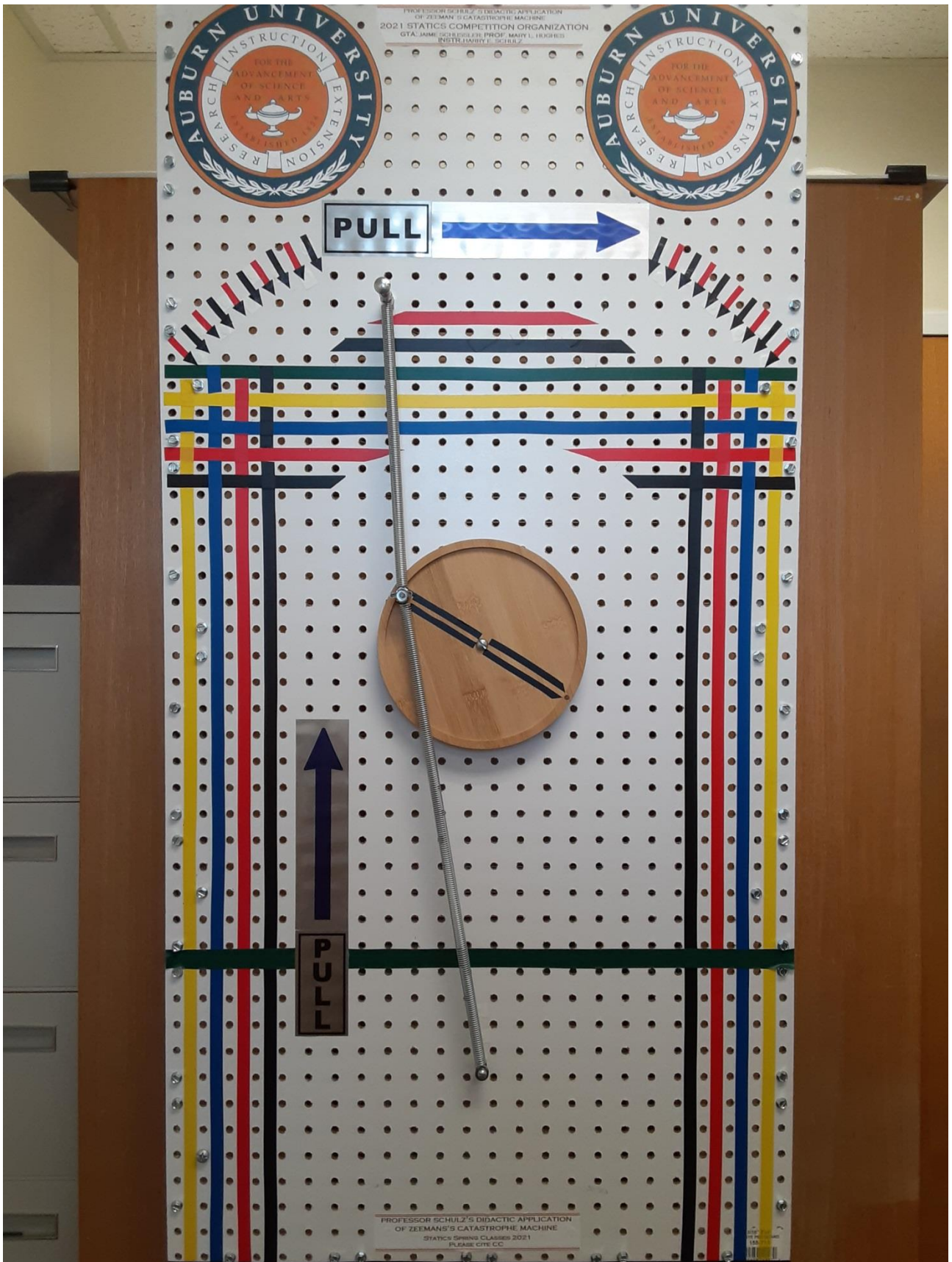


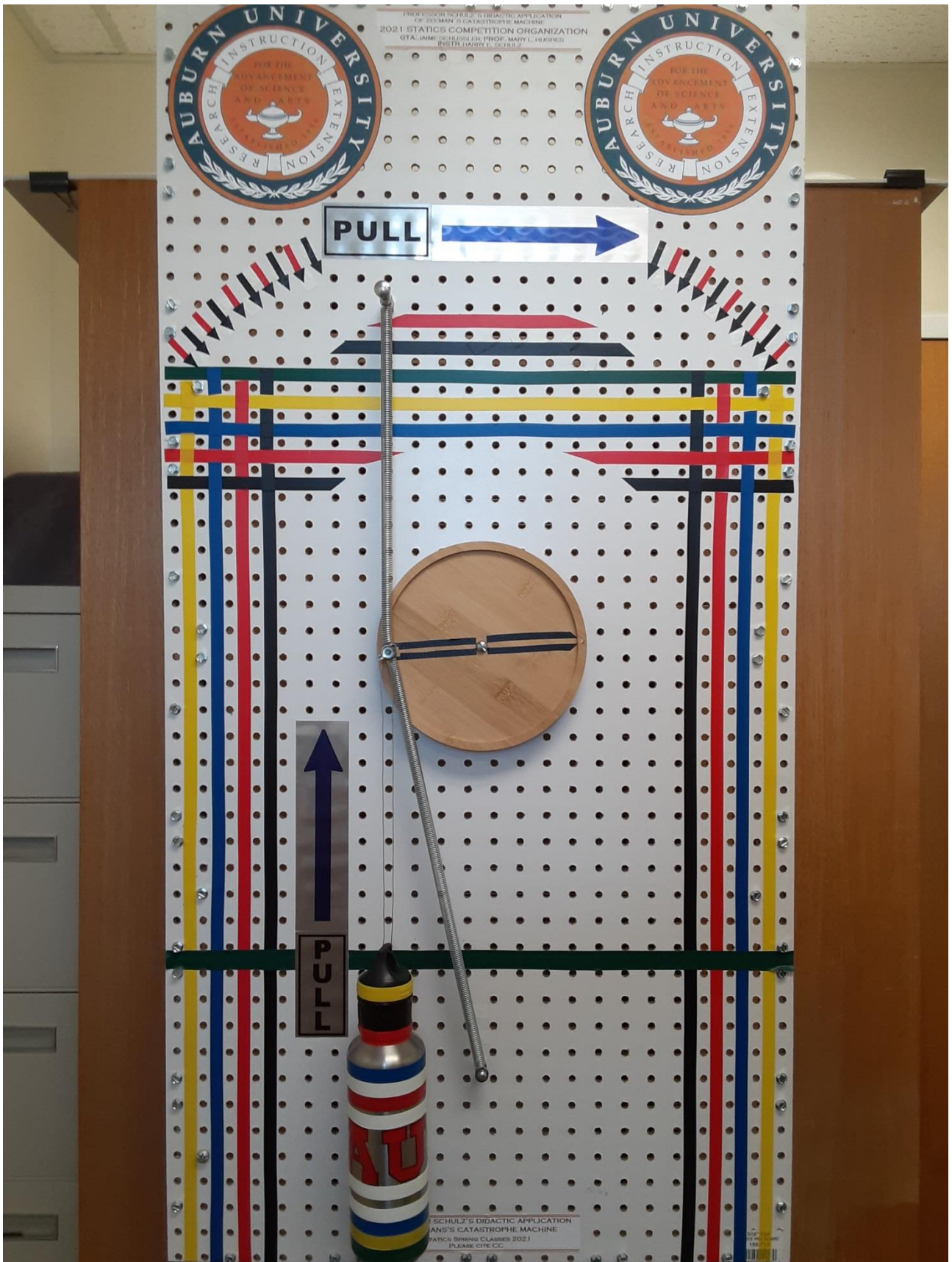


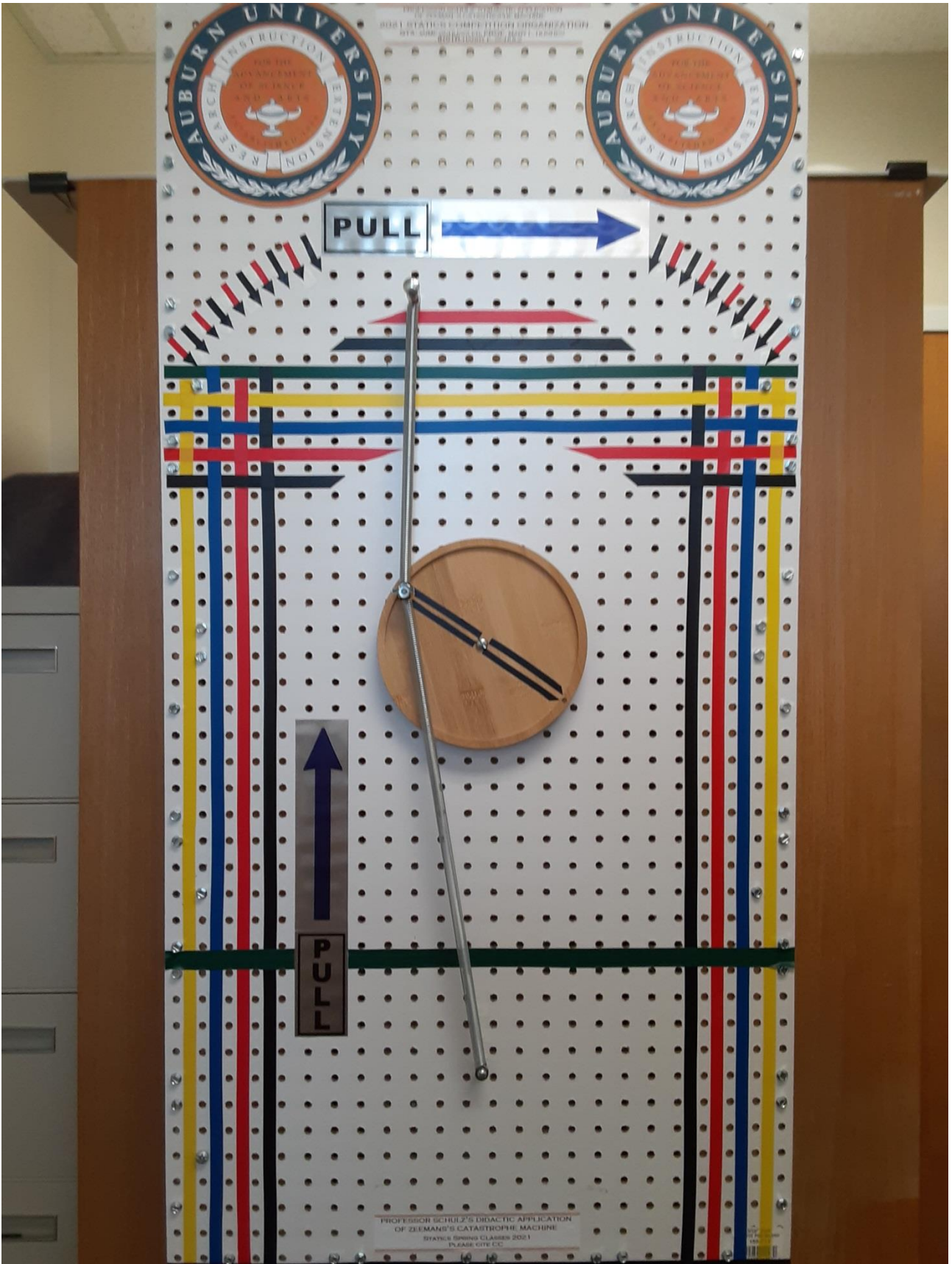




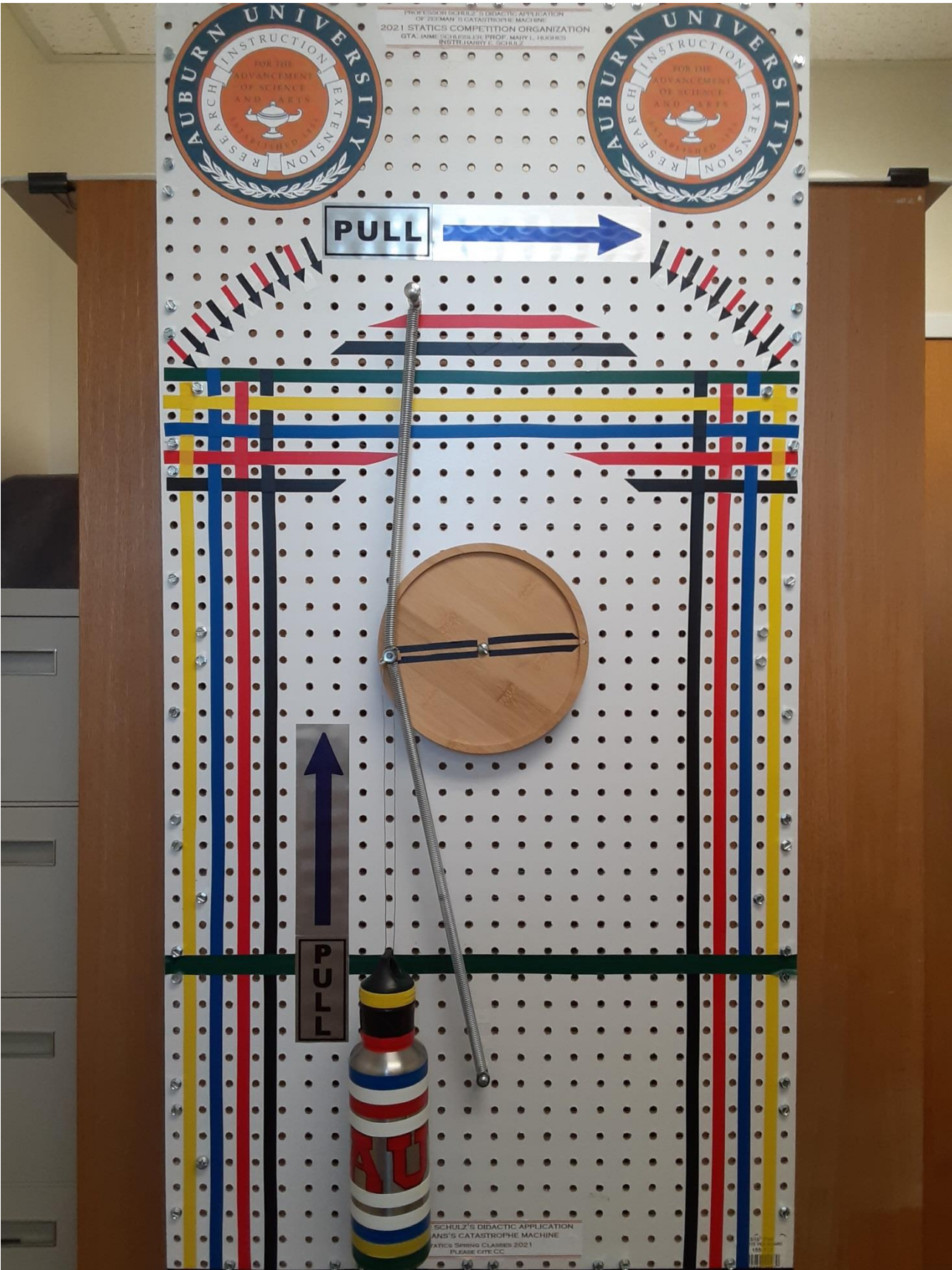


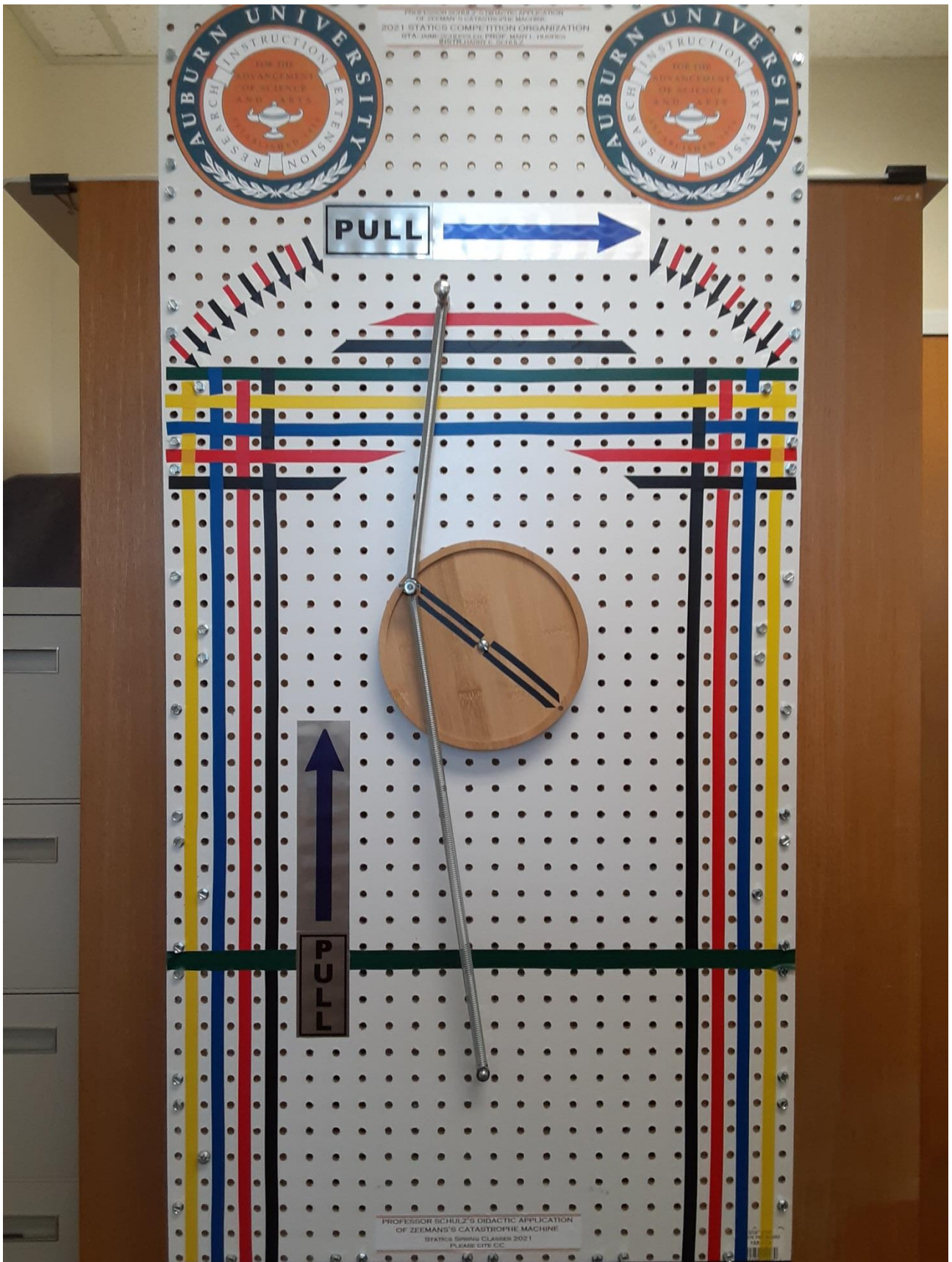


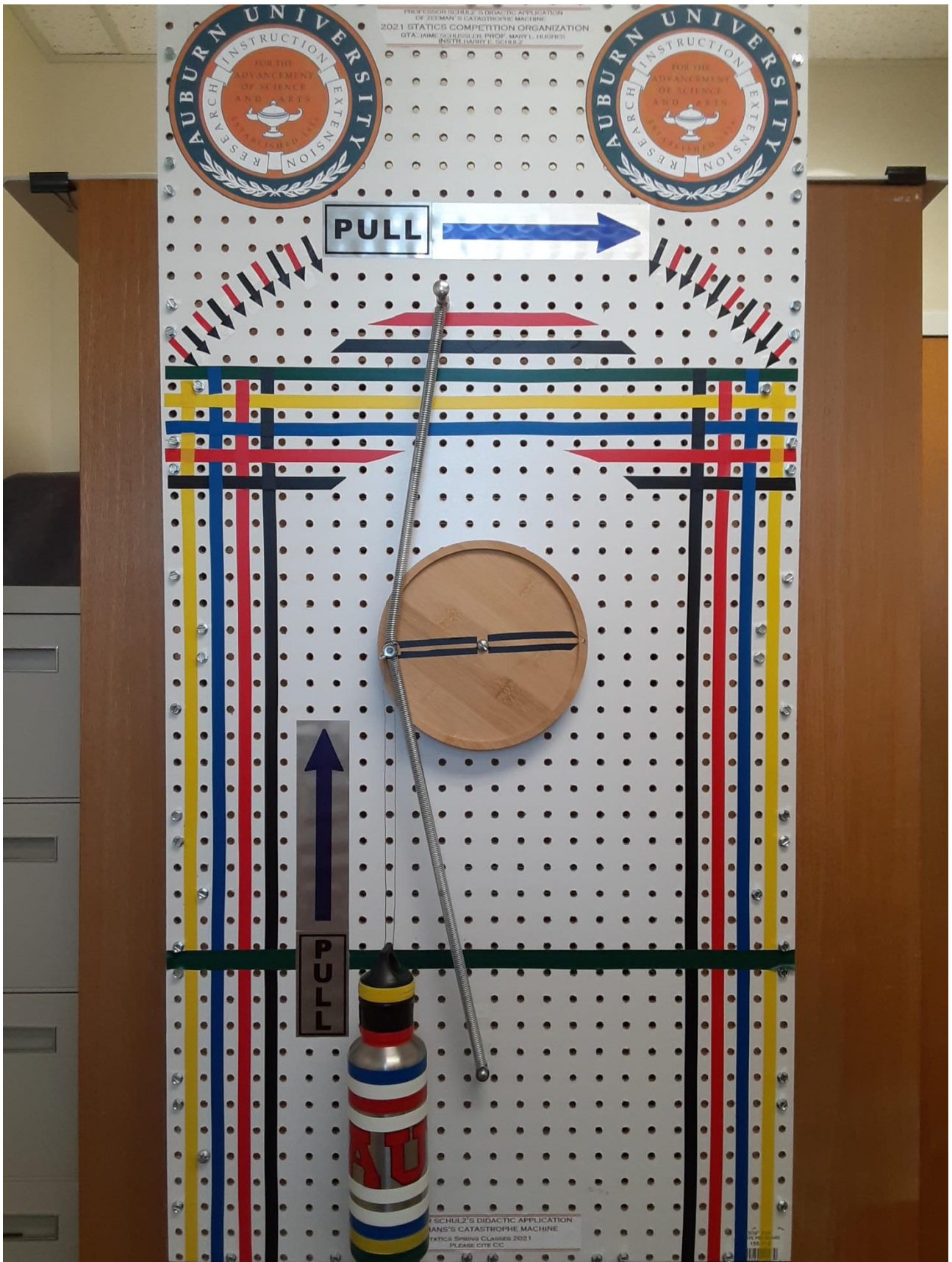


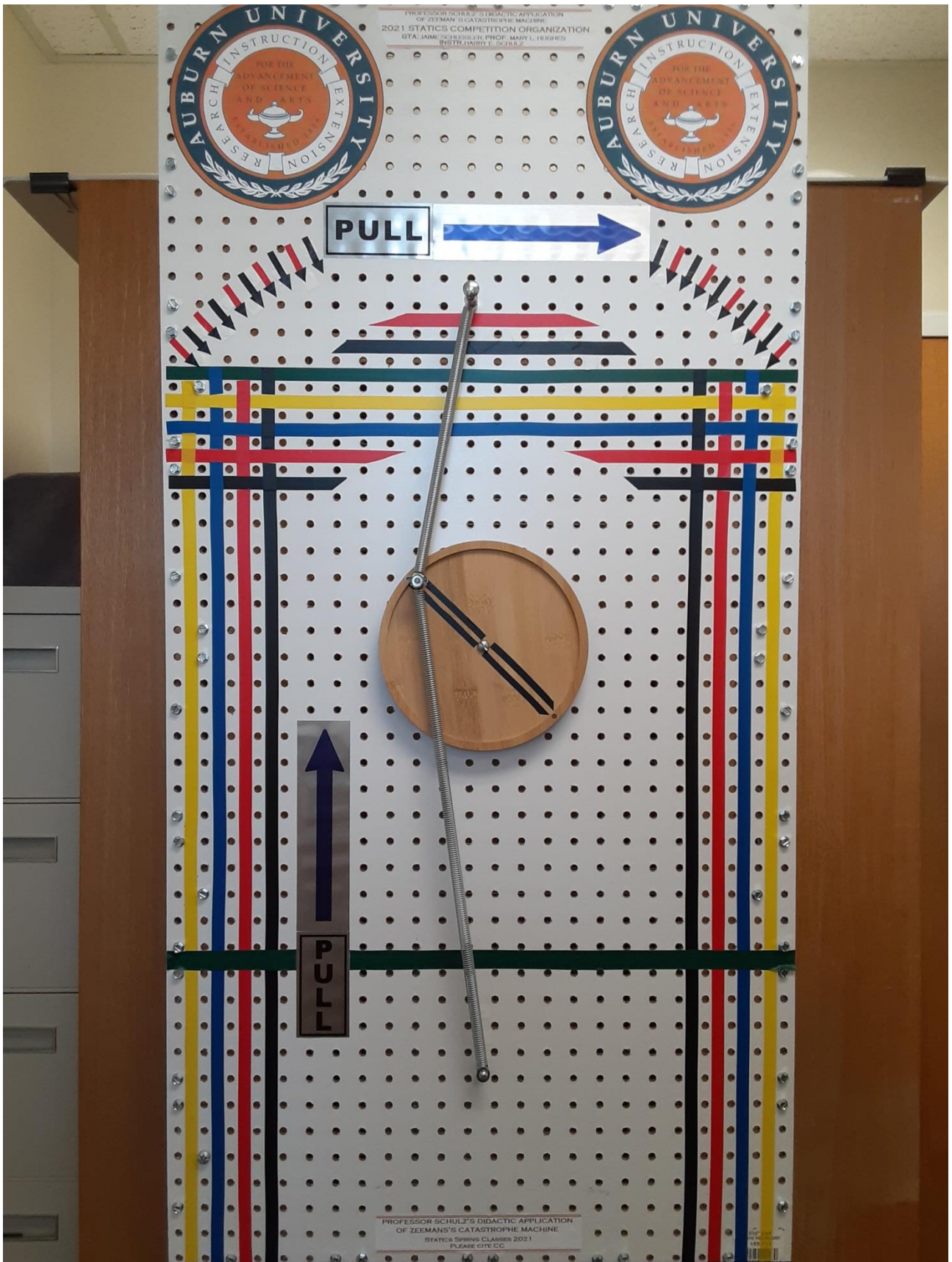


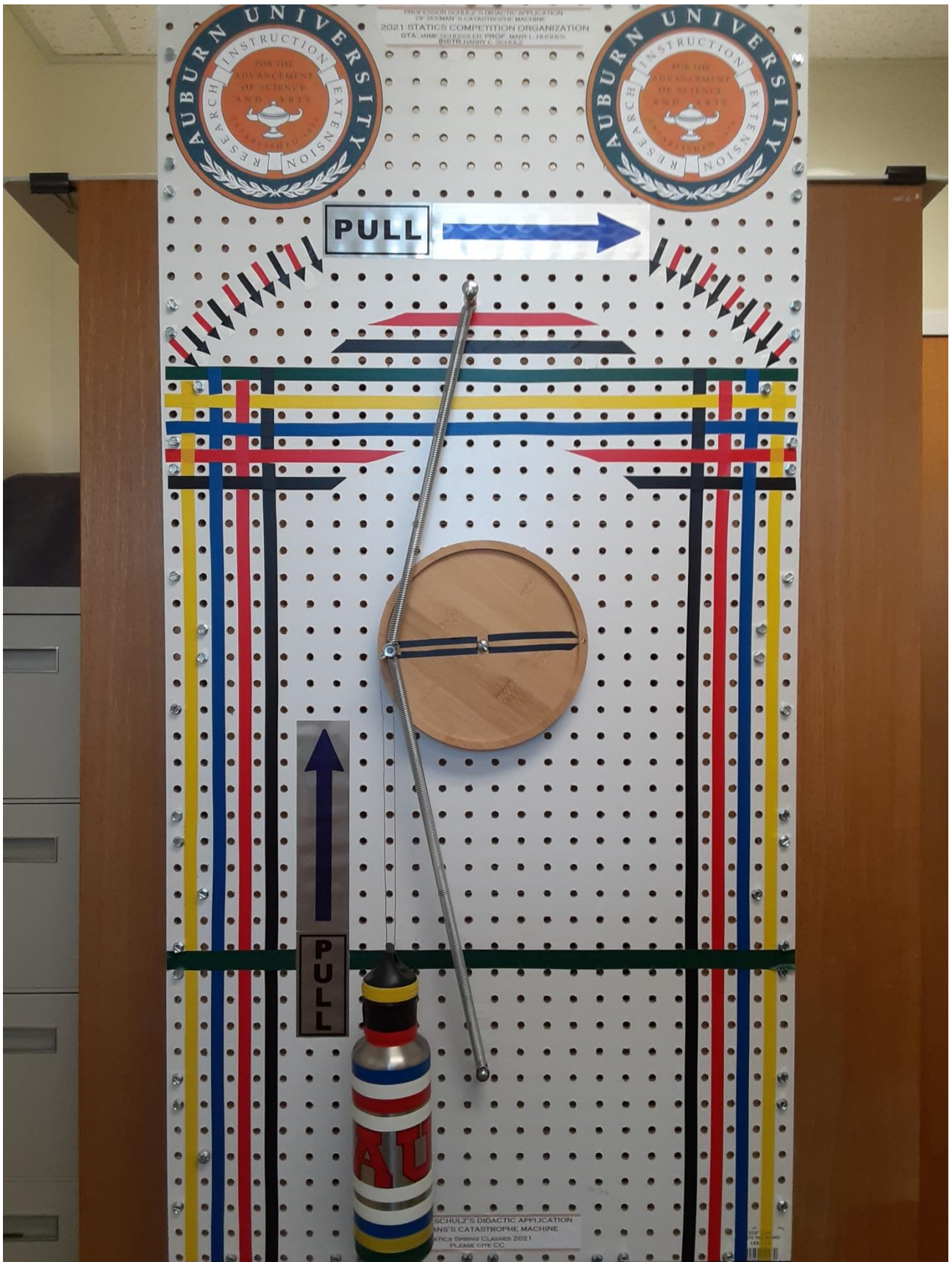


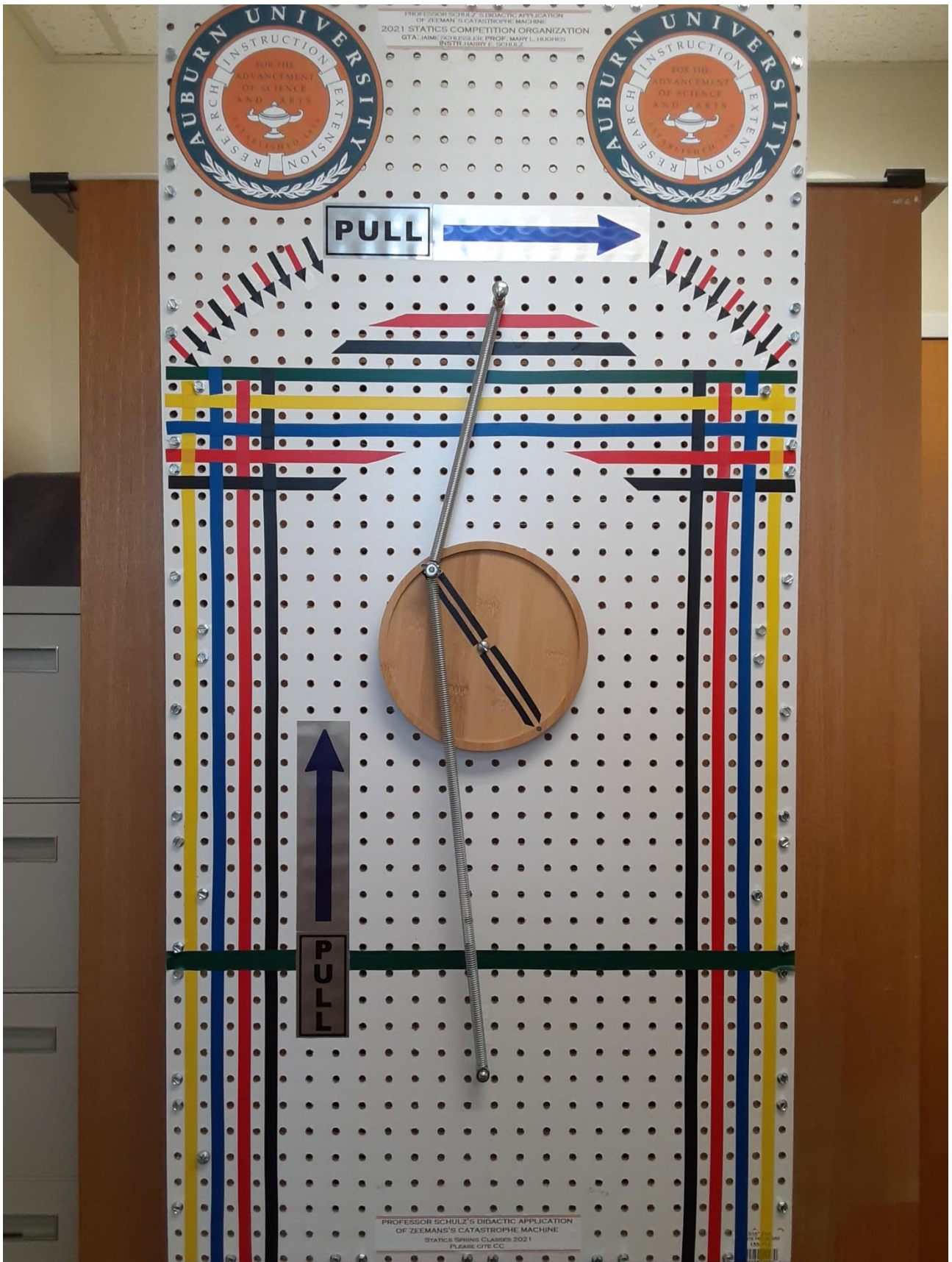


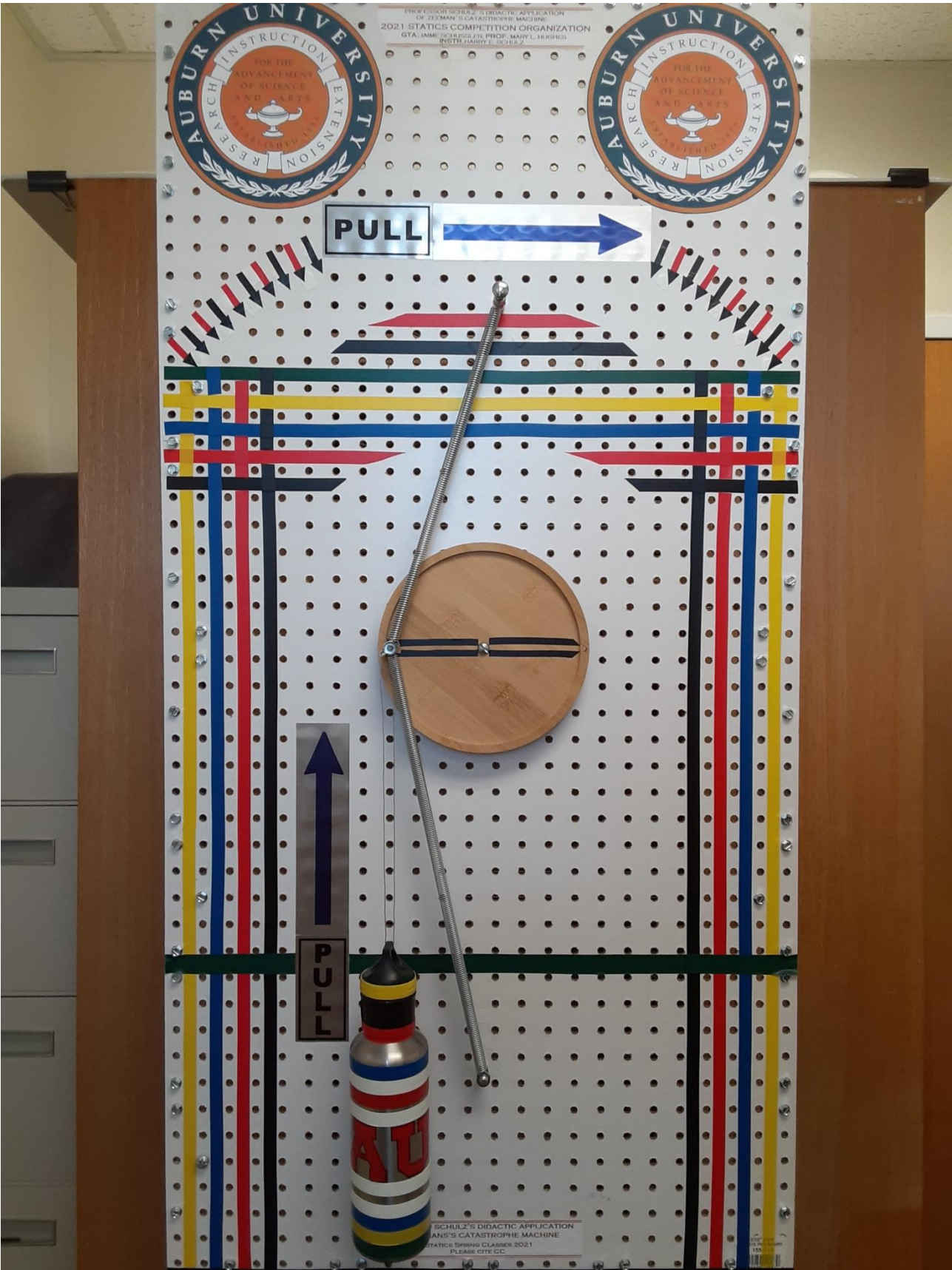


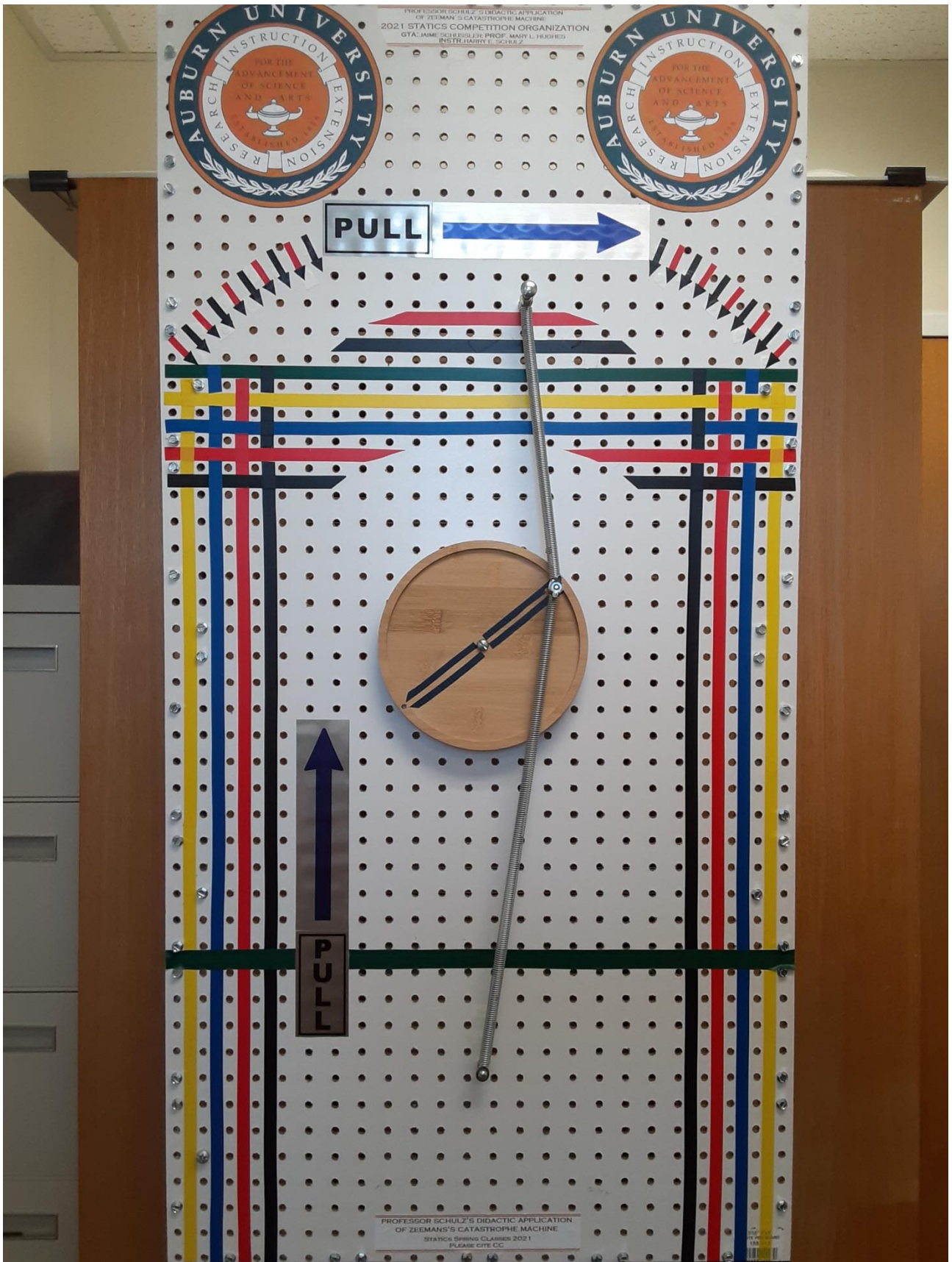




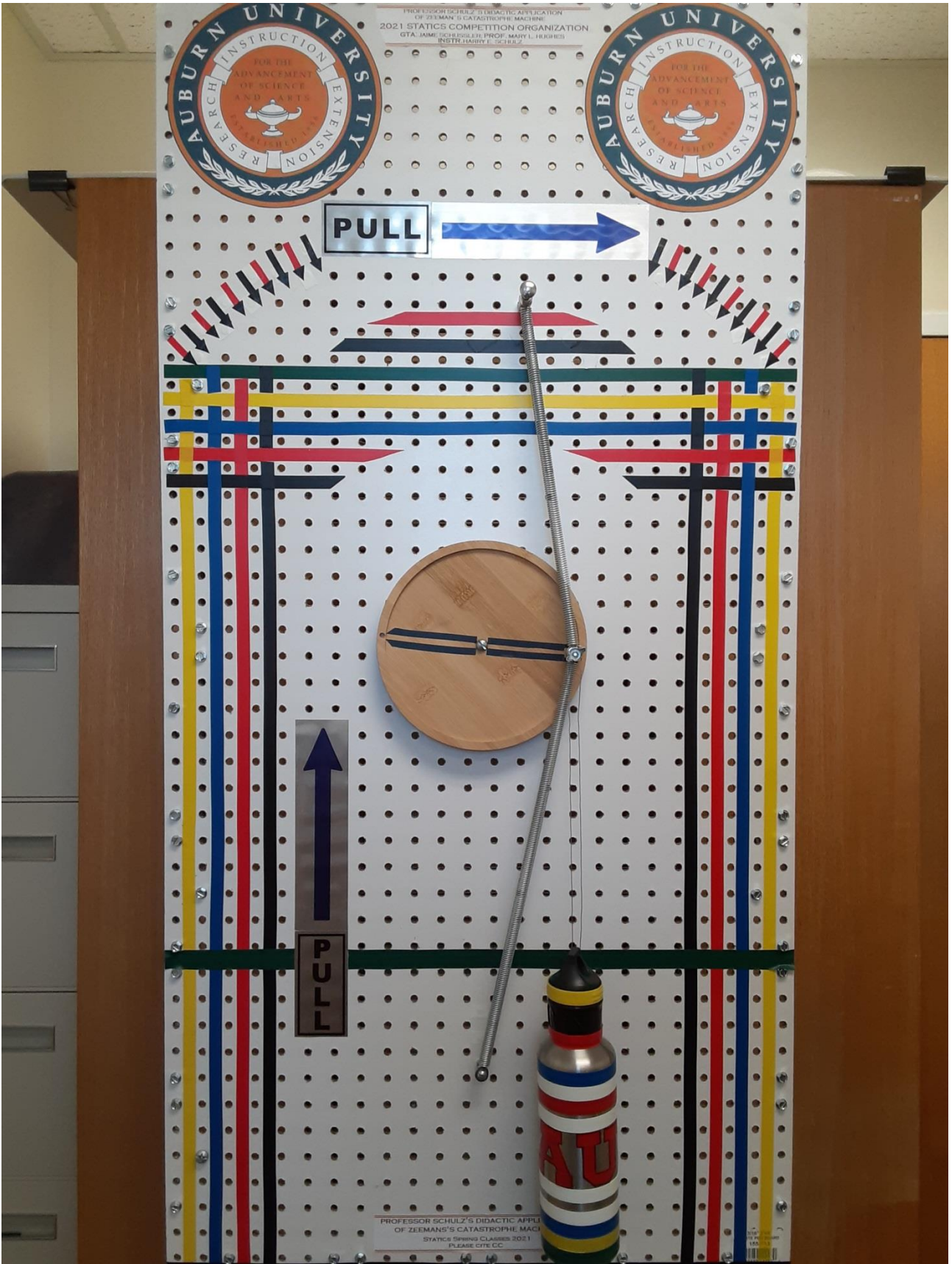












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GOOD LUCK TO ALL STUDENTS THAT GO THROUGH THIS  
NICE STATICS PROBLEM

GOOD LUCK TO THE TEACHERS THAT APPLY THIS  
EXPERIMENT IN THEIR CLASSES  
AND THANK YOU FOR USING THIS DIDACTIC INITIATIVE  
PLEASE CITE CC

SCHULZ, H.E.; SIMÕES, A.L.A. (2021) DIDACTIC APPLICATION OF ZEEMAN'S CATASTROPHE  
MACHINE: EXPERIMENTAL DATA FOR COMPETITION IN STATICS CLASSES. SPRING TERM  
2021. DEPT. OF CIVIL AND ENV. ENGG., AUBURN UNIVERSITY, AL., USA. COLLABORATION  
WITH FEDERAL UNIVERSITY OF BAHIA, BRAZIL.

1<sup>ST</sup> APPLIED AT AUBURN UNIVERSITY



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# APPENDIX I

## RULES OF THE COMPETITION

### PLEASE CITE CC

SCHULZ, H.E.; SIMÕES, A.L.A. (2021) DIDACTIC APPLICATION OF ZEEMAN'S CATASTROPHE MACHINE: EXPERIMENTAL DATA FOR COMPETITION IN STATICS CLASSES. SPRING TERM 2021. DEPT. OF CIVIL AND ENV. ENGG., AUBURN UNIVERSITY, AL., USA. COLLABORATION WITH FEDERAL UNIVERSITY OF BAHIA, BRAZIL.





1<sup>ST</sup> STATICS COMPETITION - CIVIL ENGINEERING  
DEPT. OF CIVIL AND ENVIRONMENTAL ENGINEERING  
AUBURN UNIVERSITY  
STATICS – ENGR 2050 – SPRING 2021  
INSTRUCTOR: HARRY EDMAR SCHULZ/ GTA: JAIME SCHUSSLER  
PROF. MARY L. HUGHES  
COLLABORATION WITH FEDERAL UNIVERSITY OF BAHIA, BRAZIL  
PROF. ANDRÉ LUIZ ANDRADE SIMÕES



## Dear Student:

Welcome to the 2021 Spring Statics Class Competition!

You are invited to participate in the competition with a group of your peers. The theme of the Competition is *Equilibrium of Forces and Moments*. This competition and study use the original experiment known as “Zeeman’s Catastrophe Machine”, which was proposed for the study of topologic aspects of special functions unified under the name of “Catastrophe Theory” (René Thom, 1960’s). It is a well-known device, which you will become familiar with in this experiment.

A similar device is presented here, adapted from Zeeman’s Catastrophe Machine, which was built for this competition to allow multiple measurements of springs in fixed positions. This competition is focused on the concepts worked out in the Statics Lectures. The responses to this competition should encompass the principles and material covered in the course thus far.

## 1. Groups:

The groups were composed with both in-person and online participants, so communication and cooperation is essential to perform well in the competition. Contact your group to organize the work and ensure all team members are participating.

## 2. Methodology and Data Collection:

This study has theoretical and experimental parts. In experimental studies, including the present competition, several sample measurements are required to calculate statistical mean values or mean trends.

In Canvas “Modules” you will find: 1) a film containing the basic description of the experiment; 2) a folder containing 272 photographs of different conditions of the experiment, which will serve as the main data source for your calculations; 3) a copy of the present rules; and 4) a template for the final competition report.

From the photographs, you will see that the experiment is composed of a base panel with points equally spaced, forming the Cartesian plane. These points were used to obtain the photographs. There are parallax effects in the images, but you must be able to recognize the point in use. To have a common reference point for comparative analyses, consider the origin\* of the coordinate system at the center point of the circle on the device.

\*Note: that the origin is in the intermediary position between the points of the base panel, as depicted in Figure 1.

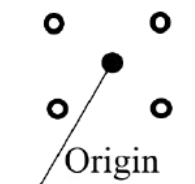


Figure 1: The origin at the intermediary position between the points on the panel.



1<sup>ST</sup> STATICS COMPETITION - CIVIL ENGINEERING  
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INSTRUCTOR: HARRY EDMAR SCHULZ/ GTA: JAIME SCHUSSLER  
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PROF. ANDRÉ LUIZ ANDRADE SIMÕES



This competition requires basic statistical analysis. If you are unfamiliar with the statistical methods required in this competition, plan to reach out to professors of statistics or other resources for help your books, internet lectures, etc.).

If needed or desired, manual measurements directly performed on the Machine can be conducted. These measurements allow for the positioning of the free end of the free spring along the base panel to be changed. No use of auxiliary weights is permitted. No use of devices for measurement of forces is permitted. No use of auxiliary springs or elastics or deformable material is permitted.

### 3. Measurement Dimensions:

The distance between the points of the panel (Cartesian plane) is 1 inch (2.54 cm).

The distance between the origin (Center of the circle) and the junction point of the two springs is 3.42 in. (8.7 cm.).

The distance between the origin (Center of the circle) and the lowest point of fixture of the fixed spring is 16 in. (40.64 cm).

The “length of rest” (no force applied) of the free spring is 7.4 in. (18.9 cm.).

The weight shown in half of the photographs has a mass of 978.8 g.

### 4. Questions for Analysis:

Using one or more sets of data with a minimum number of 30 different points:

4.1 – Find the spring constants of both springs used in the device (free spring and fixed spring).

4.2 – Find the initial length (length at rest, or length without applied force) of the spring that has both extremes fixed (fixed spring).

4.3 – Observing the behavior of the machine when pulling the free end of the free spring around the origin, generate (x, y) ordered pairs (integers or fractions) for the position of the free end of the free spring for the onset of the changing events (sudden change of the position of the circle). Plot the (x, y) ordered points in a cartesian graph to visualize their behavior. Through regression analysis (statistical procedure) propose a best fit equation for the obtained behavior of the (x, y) ordered pairs. Assume direct reflection properties about the y axis.

4.4 – Control the position of the junction of the two springs so that it stays at  $y=0$  and between quadrants 2 and 3 of the cartesian plane while moving the free-spring.

Under this condition, generate a set of free spring-end (x, y) ordered pairs. Plot the ordered pairs in the cartesian plane. Using the concepts of Statics, calculate either the theoretical curve  $y=f(x)$  or its inverse  $x=f^{-1}(y)$  and plot the curve with your measured points. Calculate the correlation coefficient between your experimental points and the theoretical curve.

4.5 – Explain the sudden change of position of the circle while you move the free end of the free spring.

In all questions you can use the positions indicated by the grid (nodes or holes) and also intermediary positions (between the nodes or holes). You must register all the data you are collecting or interpolating from the furnished data, and present them in ordered manner (clearly explained and linked to the photographs) in an appendix of your report.



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## 5. Project Report:

A template of the final report is provided in the Canvas “Assignment” and includes:

Cover page

Abstract

Background

Analysis

Conclusions

References

Appendices (Tables of data, complex derivations, etc.)

## 6. Timeline:

The deadline for report submission is Friday, April 16<sup>th</sup>, 2021; however, this is a rolling deadline, meaning you can submit any time between now and April 16<sup>th</sup>, 2021.

## 7. Evaluation and Award:

There are 7 total groups between the two statics sections. Of these groups, the top three performing groups will be awarded. Performance will be evaluated based on the correctness of questions 4.1 and 4.2, the adequacy of answers for 4.3 and 4.4, and understanding of behavior explained in 4.5.

5.1 – First place:

23 bonus points in each of the activities of Notes, Homework, and Quizzes and a gold ribbon to confirm bragging rights!

5.2 – Second place:

Grades: 20 bonus points in each of the activities of Notes, Homework, and Quizzes and a silver ribbon.

5.1 – Third place:

Grades: 15 bonus points in each of the activities of Notes, Homework, and Quizzes and a bronze ribbon.



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If the answers of the participants coincide in terms of correctness, quality of explanations and understanding, the classification will consider the study delivery time. In this case, the group that delivers before has the best classification, and so on.

## 8. Participation:

The groups not placing in the top three will also have the chance of increasing their grades by a maximum of 10 points in the Notes, Homework and Quizzes categories of the course. To attain these points, groups must still present the correct answers and adequate adjustments.

## 9. Grading Committee:

The decision of the organization committee is final. The committee includes:  
GTA: Jaime Schussler,  
Prof. Mary L. Hughes,  
Instr. Harry E. Schulz.

To all the participants: Good work and good luck!



You are a special part of our university.

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# APPENDIX II

## TEMPLATE OF THE REPORT

PLEASE CITE CC

SCHULZ, H.E.; SIMÕES, A.L.A. (2021) DIDACTIC APPLICATION OF ZEEMAN'S CATASTROPHE MACHINE: EXPERIMENTAL DATA FOR COMPETITION IN STATICS CLASSES. SPRING TERM 2021. DEPT. OF CIVIL AND ENV. ENGG., AUBURN UNIVERSITY, AL., USA. COLLABORATION WITH FEDERAL UNIVERSITY OF BAHIA, BRAZIL.



PRODUCTION AT AUBURN UNIVERSITY, AL, USA.

EDITION AT FEDERAL UNIVERSITY OF BAHIA, BA, BRAZIL.





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## ZEEMAN'S MACHINE STATICS APPLICATION

Group #: *(Alphabetic order first name)*

*NAME, NAME*

*NAME, NAME*

*NAME, NAME*

*NAME, NAME*

*NAME, NAME*

ENGR 2050 STATICS  
Spring 2021  
Auburn University  
Dept. of Civil and Environmental Engineering



## 1. BACKGROUND

*(Explanation of work)*

*Explain the context of this competition as applied to the concepts covered in the lectures of the 2050 Statics Course. Explain the questions. Do not exceed 2 pages.*

## 2. ANALYSIS

*Do not exceed 10 pages.*

*Introduction to section.*

### 2.1 – Theory

*Show the derivation of the equations used for the answers and the statistical procedures. Bibliographical references are indicated here (book of Hibbeler, Statistics texts, etc), as well as internet sites. The help of teachers should also be included and referenced. If some theoretical derivation is too long, you can add it in the Appendixes.*

### 2.2 – Data

*Explain the origin of data used for analysis (from the photos and/or own measurements in the same machine). Reference photos.*

***Organized Data Tables shall be added as Appendixes (mandatory). You will have access to images, from which you will generate numerical values. Link the numerical values of the variables you are using to the corresponding photos. Studies without the Data Tables will not be considered.***

### 2.3 – Results

*Answer the questions presented in the competition rules sheet:*

*Show the values asked for the spring constants and the initial length of the fixed spring.*

*Show the adjustment of the best fit equation for the changing events.*

*Show the adjustment between observed ordered pairs and theoretical prediction, and the correlation coefficient.*

*Present your understanding of the cause of the sudden change of position of the circle.*

### 3. CONCLUSIONS

*Summarize findings. Do not exceed 1 page.*

## 4. BIBLIOGRAPHIC REFERENCES

*(Alphabetical order)*

Hibbeler, R.C. (2016) Statics – Engineering Mechanics, 14<sup>th</sup> Ed., Pearson Prentice Hall ED., 706 p.

1. *Indicate further references following the format of Hibbeler.*
2. *Internet sites cited in the text, copy here in alphabetic order.*
3. *Help of teachers: As example, indicate as:*

Einstein, A. (2021) Professor of Physics, Institute for Advanced Study, Princeton, USA. Helped to clarify the statistical treatment of the experimental data.

## APPENDIXES

A.1. – Data Tables **required**

A.2. – *Title as needed*  
*Long derivations, extra details, etc.*