Culturally Responsive STEM Lesson Plan:

NATIONAL MAGLAB
Research Experiences FOR TEACHERS

Mu of the Shoe Lab

Lesson Objectives

- **Calculate and define the coefficient of friction (μ) between different shoes and surfaces.**
- **Examine the effects of frictional forces on the motion of objects.**
- **Apply findings from experiment to a sports scenario. When would a high coefficient of friction (μ) be helpful? When would a lower force due to friction be helpful?**

Next Generation Science Standard

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

STEM Rationale for Lesson

- Experience using sensors and measuring tools to collect data
- Practice calculating an average of multiple trials
- Practice designing a controlled experiment
- Practice identifying relationships between variables
- Examine how forces (such as friction) affect motion of objects

Culturally responsive connection

- Analyze how cost of shoe may affect friction
- Analyze how brand of shoe may affect success or injury prevention in a sport
- Tie in students' interests with different sports or activities on different surfaces (ice skating, running on grass, running on wet pavement)
- Students will explicitly discuss how access to resources, culture, role models and representation affect success in a sport.

Materials Needed:

Provided by Teacher:

1. Worksheet provided in Appendix A
2. Spring Scale or Vernier Force Sensor & Labquest or Graphical Analysis™ 4.4 Update for Computers, Chromebooks, and Android (Chromebook)

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3. Calculators
4. Extra shoes (combination of athletic, slippers, flip flops, and heels could be interesting)
5. Optional: Students can bring in extra pairs of shoes to test coefficient of friction

Activate Prior Knowledge

1. Definition of force, net force, balanced forces, unbalanced forces, constant velocity, acceleration, normal force, gravitational force
2. Free body diagrams of objects moving at constant velocities, at rest, and accelerating
3. Applications of inertia and its relationship to mass
4. Difference between mass and weight
5. Conversions to SI units

Lesson Introduction

1. Kinetic Questions (4 corners)

Set up signs in four corners of the room that say: *Agree, Disagree, Strongly Agree, Strongly Disagree.* On the whiteboard or projector, display each of the following statements one at a time. Students will move to the corner of the room that matches their opinion on the statement. Ask a few students to share out their reasoning or have them discuss with the people in their corner.

- Individuals with more access to resources are more likely to be successful athletes.
- The gear and equipment that athletes wear is what most strongly determines their performance.
- All individuals have the potential to be successful athletes.
- Training is the top predictor of an athlete's success.
- Environmental and health factors are the top predictor of an athlete's success.
- Seeing someone that looks like you compete in that sport is the top predictor of an athlete playing that sport.

Lesson Activity:

1. Students together draw a free body diagram (FBD) for the shoe being pulled to the right at a constant velocity. Students compare FBDs with group members.
2. Students choose a research question from the list in linked worksheet (under Materials) or write their own (if approved by teacher and relating to friction).
3. Students hypothesize individually how they think the independent variable will affect the force of friction.
4. Students will follow the inquiry questions and complete the data table by pulling their shoe from a spring scale hook around laces or a force sensor hook around laces. They will record force values in Newtons and modify either surface, type of shoe, or weight of shoe.

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5. Students will calculate mu (coefficient of friction, μ) of the shoe and compare to googled values of similar surface combinations.
6. Students will answer analysis questions and connect to a sport of their choosing as they think about advantages and disadvantages of high and low coefficients of friction.
7. Students can record and compare shoe brands in class data sheet or on poster paper.

Lesson Assessment

Options:

1. Analysis questions
2. Exit ticket (draw a FBD or analyze a FBD for a sample shoe's friction values)
3. Verbal quiz summarizing procedure and process for finding mu and why the procedure helps us find the value
4. Draw a mini cartoon strip to explain friction coefficients and forces to a 1st grader
5. Choose a sport and students analyze that sport and connect what they now know about friction, make recommendations for shoe type/surfaces that are safe etc.

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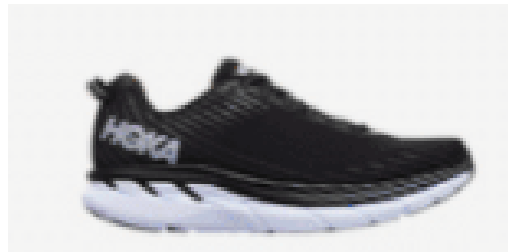

Appendix A

PD	NAME	PER

Mu (μ) of the Shoe Lab

#GOALS

- **Calculate and define the coefficient of friction (μ) between different shoes and surfaces.**
- **Examine the effects of frictional forces on the motion of objects.**
- **Apply findings from experiment to a sports scenario. When would a high coefficient of friction (μ) be helpful? When would a lower force due to friction be helpful?**

RESEARCH QUESTION OPTIONS

1) How does mass of shoe affect $F_{friction}$?
2) How does the style/brand of shoe affect $F_{friction}$?
3) How does surface affect $F_{friction}$?
4) Other:

HYPOTHESIZE

1)
2)
3)
4)

PRE-LAB

a) Draw a labeled FBD for a shoe sliding to the right along the floor with a constant velocity. The shoe is being pulled by a spring scale or a digital force sensor. You'll come back and add values to this FBD after data collection.

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b) Are the x-direction forces balanced or unbalanced? (Circle one)
c) Are the y-direction forces balanced or unbalanced? (Circle one)

PROCEDURE

1. Use a spring scale or a digital scale to measure the WEIGHT of 3 different shoes in Newtons. Weight = $F_{gravity}$ = mg   g = 9.8 m/s/s

Shoe brand/style	$F_{gravity}$ aka Weight (N)

2. Choose **one of the 3 research questions** from page 1 and write it here:

3. List **3-5 control variables** for your experiment here:

4. Measure and record the $F_{applied}$ or F_{spring} required to move the shoe at a constant velocity across the surface.

Independent Variable =	$F_{applied}$ or F_{spring} (N)

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5. Why should the $F_{applied}$ or F_{spring} be equal to the $F_{friction}$ on the shoe?

6. Why should the $F_{gravity}$ be equal to the F_{normal} on the shoe?

7. Use your data to calculate the mu (μ) of the shoe. Your value of mu (coefficient of friction) will be unitless because you are dividing Newtons by Newtons.

$$\mu = F_{friction}/F_{normal}$$

8. Google some coefficient of kinetic friction values (μ_k) that are similar to your shoe sole/surface combo and record the value here:

9. Now add something to the shoe so that it approximately doubles the weight of the shoe. Record the $F_{applied}$ required to slide the shoe at a constant velocity on the same surface you used for Step 7. Calculate the mu (μ) of this heavier shoe.

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10. Does weight affect $F_{friction}$? Why or why not?

11. Does weight affect mu **(μ)** of the shoe? Why or why not?

12. How could mu (μ) of surfaces and shoes affect acceleration of an athlete?

13. Why do some sports require special shoes?

14. How is friction involved in your sport? In what cases would more friction be beneficial? In what cases would less friction be helpful?

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15. Write out a scenario related to your sport that involves an object or athlete moving on a surface with friction. Draw the corresponding FBD for that scenario.

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