**How to find coefficients of friction through an inclined plane**

*A Practical Method To Measure Coefficients For Frictional Force*

Subject: Physics.

Time Allocation: Thirty-five minutes.

**Performance Objectives**

Applying the skills of teamwork, students work cooperatively to find out coefficients of friction for surfaces of metal on wood and metal on metal.  After completing this class activity, students should be able to

1. understand that a coefficient of friction could be determined via an inclined plane;

2. collect experimental data and calculate the corresponding results of coefficient;

3. compare the values of coefficient generated from different pairs of surfaces.

**Components for Cooperative Learning**

1. Team size: four students.

2. Assignment to team: If there are thirty-two students in the class, teacher will assign a

number to each student starting from 1 to 8.  Next, all the “one”s will make up a team,

all the “two”s will make up another team, all the “three”s will make up the third team,

and so forth.  Teacher will also ensure that the students are equally distributed among

the teams depending on their talents.

3. Roles in each team:

    Messenger ---- reading the class instructions to direct this activity;

    Handler ---- to pick up and return all class activity materials for his/ her team;

Operator ---- following the given procedure to carry out the experimental trials;

Recorder ---- to record the observation results and to calculate the related data.

4. Positive interdependence: This class activity should be done cooperatively.  Thus,

every team member must be assigned a role to make a positive contribution for the

completion of the class activity.  Each team should fill in the data sheet for the results

of this activity; its team members should agree with the team observations and should

be able to explain the results.

5. Individual accountability: While doing this activity, each team member is expected to

write down the common observations for the experiment.  Furthermore, every student

must be able to explain the purpose of the class activity.  Teacher may call individuals

to come to the board and to present their results.

 6. Expected behaviors and monitoring: Teacher will expect to see all team members

participating in the class activity and performing his/her role.  Every student should

know how to fill in the data sheet for the class activity.  During the class, teacher will

circulate the room to monitor the progress of teamwork and to guide students with

helpful hinds whenever it is necessary.

7. Criteria for success and closing: Teams that successfully complete the class activity

and record the data accurately in the data sheet will earn two points of credit for this

class activity.  Finally, teacher will distribute the evaluation sheet to have students

assess their cooperative behavior and comment on each team performance.  Moreover,

teacher could ask students to express their opinions on this activity, for instance, how

to improve their performance in the teamwork? what are the suggestions for the better

outcome on cooperative learning?

**Background Introduction**

A convenient device to measure the coefficients of friction for a pair of materials is an inclined plane device.  In order to calculate ms (static coefficient), the slope (angle) of the inclined plane is increased gradually until the object first begins to slide down the plane.  At that angle, the component of the weight of the object (Fg) parallel to the plane has just succeeded in overcoming the force of static friction.  Based on the Newton’s second law of motion, this parallel component (Fgsinq) is approximately equal to the static frictional force (msFN): **Fgsinq = msFN**.  Through “free-body” force analysis, a normal force (FN) that the object acts on the plane surface is equivalent to the weight of the object perpendicular to the plane (Fgcosq): **Fgcosq = FN**.  Mathematically combining the above two equations will generate a useful calculation formula: **ms= tanq**, the coefficient of static friction is determined by the angle of the inclined plane, which is a pure number and has no unit.

**Materials for Class Activity**

1. Eight sets of each following items:

* copper object (e.g. penny)
* wood surface (e.g. letter size clipboard)
* metal surface (e.g. base of a ring stand)
* ruler, protractor, and scientific calculator

2. One set of copy for each student:

* introduction and procedure sheet
* experimental data sheet
* activity evaluation sheet

**Class Activity Procedure**

1. Place a penny in the center of a clipboard, and slowly lift up one end of the clipboard to generate the effect of an inclined plane.

2. Gradually increase the slope of the plane until the penny first begins to slide down, and record the angle of the inclined plane on the data table below.

3. Repeat Step 1 and Step 2 twice, and apply a formula **ms= tanq** to calculate the coefficient of friction for those three trials.  Next, find out the average of the coefficient on the surfaces between copper and wood.

4. Use the base surface of a ring stand (must be smooth without rust) as a metal surface to repeat the above steps for another three trials, and then calculate the average of the coefficient on the surfaces between two kinds of metals.

**Learning Outcomes**

1. Results from each team

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | Angle on clipboard(inclined plane ofwood surface) | **ms= tanq**coefficient ofcopper on wood | Angle on ring stand(inclined plane ofmetal surface) | **ms= tanq**coefficient ofmetal on metal |
| Trial 1 |   |   |   |   |
| Trial 2 |   |   |   |   |
| Trail 3 |   |   |   |   |
| Total |   |   |   |   |
| **Average** |   |   |   |   |

2. Results from entire class (eight teams)

|  |  |  |
| --- | --- | --- |
|   | **ms**of copper on wood | **ms**of copper on metal |
| Team one |   |   |
| Team two |   |   |
| Team three |   |   |
| Team four |   |   |
| Team five |   |   |
| Team six |   |   |
| Team seven |   |   |
| Team eight |   |   |
| Class total |   |   |
| **Class average** |   |   |

Homework Assignment

Design another mechanical device, besides the inclined plane, which could be utilized to determine the coefficients of frictional force on various pairs of materials.

***REFERENCE ON SCIENCE STANDARDS***

            This Action Plan aligns with following Science Teaching Standards on the *National Science Education Standards*  (National Academy Press, 2001):

Standard A ---- Plan an inquiry–based science program.

* Select science content and adapt and design a curriculum to meet the interests, knowledge, understanding, abilities, and experiences of students.
* Select teaching and assessment strategies that support the development of student understanding and nature a community of science learners.

Standard B ---- Guide and facilitate learning.

* Focus and support inquiries while interacting with students.
* Encourage and model the skills of scientific inquiry, curiosity and openness to new ideas and skepticism that characterize science.

Standard C ---- Engage in ongoing assessment of teaching and student learning.

* Analyze assessment data to guide teaching.
* Guide students in self-assessment.

Standard D ---- Design and manage learning environments that provide students with the time, space, and resources needed for learning science.

* Create a setting for student work that is flexible and supportive of science inquiry.
* Identify and use resources outside the school.

Standard E ---- Develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

* Display and demand respect for diverse ideas, skills, and experiences of students.
* Model and emphasize the skills, attitude, and values of scientific inquiry.

Standard F ---- Participate in the ongoing planning and development of the school science program.

* Plan and develop the school science program.
* Participate in decisions concerning the allocation of time and other resources to the science program.