FSEA PROJECT PLANS

September 14, 1998

MARBLE SLIDE
MS1

Applicable Grades	4th through 9th
Number of Members Per Team	Two
Number of Slides Per Team	One
Number of Sessions	Two to Three

SKILLS AND ENGINEERING CONCEPTS DEVELOPED:

Kinetic and potential energy, horizontal and vertical velocity, data recording, analysis, testing procedures.

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Opinions expressed are those of the authors and not necessarily those of the foundation.

OBJECTIVE

The objective of this project is to teach the students some basic concepts regarding energy (kinetic and potential), acceleration velocity, friction and vectors. In addition it will teach them how to perform a scientific experiment and how to measure and record the resultant data.

This will be accomplished by having the students repeatedly roll a marble down a 24" tube and then measure and record the distances the marble travels. The angle between the ground and the tube will be varied which will change the distance the marble will roll (this project is best performed on carpet).

PROJECT DESCRIPTION

This project requires some discussion by the mentor on some basic principles of physics. For some basic physics principles, a simplified review appears in Appendix A. A Basic program is available for Junior and Senior High School students. Appendix B contains some sample demonstrations, some general questions and answers are presented in Appendix C, and Appendix D contains some analysis. Appendix E contains a sample chart which students might use to compile and record data. The student's part of this project will be to perform some experiments based on the mentors demonstrations, and to measure and record the results for repeated trials.

For their experiment, each student team will be provided with a hollow tube 24" long, a marble and a yardstick. The objective of the experiment is to determine how far the marble will roll on the ground after being inserted into the top of the tube. Gather data based on the height of the tube and the distance traveled by the marble at each height.

The teams should adhere to the following procedure when doing their experiment.

1. Set one end of the tube on the ground and hold the other end at a certain height "***h***".
2. Insert, hold and release a marble in the tube allowing it to roll down the tube and out.
3. After the marble has stopped rolling, measure the distance "***d***" it rolled from the exit point of the tube.
4. Record both the distance "***d***" and the height "***h***" for this trial.
5. Repeat this test several times at the same height to check for consistency.
6. Change the height "***h***" and repeat the procedure.

The students should then organize their data in either a tabular format or graphic format so as to be able to utilize the information for the competition. After the initial graph is made, anomalies in the data as shown on the graph need to be reverified.

MATERIALS

FSEA will provide:

- marbles for each team
- a PVC marble slide for each team
- a computer program which will assist in calculations is available upon request by middle or high schools
- quadrille graph paper

FSEA will not provide:

- yard sticks
- a tape measure

COMPETITION

The competition is somewhat dependent upon the area and the type of surface available for the marble to roll on. A hard surface such as wood, concrete or linoleum is not desirable, as the marble will roll too far. A tight weave carpet is necessary.

The mentor should select one or two different distances as a target. Each team would then get three tries to roll their marble down the tube set at whatever height the team decides upon to come as close to the target as possible. The team would then move to the second course (if two distances are being used) and repeat the procedure.

Scoring may be done in any manner the mentor deems appropriate. One suggested scoring method would be to measure the "miss distance" between the target and the marble and use the "best" one (closest) of the three as the teams score.

For two targets, add the two best scores (one from each target) together for a "combined miss distance". The team with the lowest combined miss distance score is the winner.

An alternate scoring system could be awarding points to the teams based on their order of closeness for each target.

Example:

Closest - 25 points
Second - 20 points
Third - 15 points
Fourth - 10 points
Fifth - 5 points

Adding the results of the two trials together, the team with the most points is declared the winner.

LESSON PLAN BY SESSIONS

This is a guide only.

Session #1

Discussion of concepts such as energy (kinetic and potential), acceleration velocity, friction and vectors (see Appendix B). Pass out tubes, marbles, yardsticks and data sheets to each team. Assign an area for each team to work in. Mentors discuss graphically representing data.

Session #2

The Mentor should check each team to insure that they are taking the data correctly. Teams continue taking data.

Session #3

Hold the Competition. If all teams have completed their data tables, identify the distances selected by the Mentor for the competition and conduct the competition.

If time permits, pass out awards and have students discuss the scientific principles they have learned.

APPENDIX A

Potential Energy is the type of energy a body possesses by virtue of its position. Thus if a weight of "***w***" lbs. is raised to a height "***h***" feet, it can be stated that this object possesses Potential Energy in the amount of ***w*** x ***h*** foot-pounds.

Kinetic Energy is the type of energy a body possesses by virtue of its motion. An object traveling at a velocity "***v***" has kinetic energy proportional to the square of its velocity.

Friction is the force exerted between two objects which prevents one object from moving over the other. If the object is in motion, friction will impede this motion and slow the object down. The two types of friction are Sliding Friction and Rolling Friction. Sliding friction is by far and away the greater of the two types.

Velocity is the speed an object is moving relative to some other object--usually a stationary one.

Acceleration is the rate of change of an object's velocity due to some externally applied force. For falling objects the applied force is gravity (which results in an acceleration of 32.2 feet per second squared).

Scalar and Vector Quantities:
A scalar is a quantity which has magnitude, such as mass, density, energy, or temperature. A vector is a quantity which has magnitude and direction, such as force, velocity or acceleration.

APPENDIX B

It is recommended that the mentor perform the following demonstrations using the marble and the tube provided.

1. Hold the tube perpendicular to the ground with one end on the floor.

2. Place a marble in the opening and hold it there.

3. Explain that this marble contains potential energy due to its height and above the floor. The formula for the Potential Energy is ***w*** x ***h***.

4. Release the marble. It will hit the floor, probably bounce and move erratically. It won't roll very far in a predictable direction because the velocity attained by the marble after release is all vertical, there is no horizontal component.

5. Place the end of the tube on the floor, but this time form an angle with the floor of less than 90 degrees.

6. Insert the marble at the top of tube and hold it there. Explain that the marble has less potential energy than before because the height ***h*** is decreased. Therefore, the marble won't reach as high a velocity due to gravity. However, there will now be a horizontal component to the velocity.

7. Release the marble and watch it roll onto the floor. Draw a velocity vector on the chalkboard to represent the marble's movement. This vector can be broken up into two components, one vertically representing the fall and one horizontally. The horizontal component leads to the rolling motion after the marble leaves the tube.

8. Repeat the experiment one more time, only this time make a very small angle between the tube and the floor.

9. This time the marble possesses very little potential energy and when it rolls out of the tube it will be moving very slowly and won't travel far.

From the demonstration, the students should be able to come to the conclusion that there is some height to which the end of the tube should be raised for the marble to roll a given distance. This then forms the basis for the students' experiment, "To determine how far a marble will roll on a given surface for the height of the tube."

APPENDIX C

1. The maximum velocity the marble will have as it gets to the lower end of the tube is found by equating its potential energy at height ***h*** (***P.E.*** = ***mgh*** where ***m*** = mass of the marble) to its kinetic energy at exit (***K.E***.=1/2***mv***^{2} where ***v*** = mass velocity).

$$mgh=1/2mv^2$$

or $$v = \sqrt{2gh}$$

However, this velocity ***v*** has a vertical component and a horizontal component, each depending on the angle ***A*** that the tube makes with the surface. The angular or rolling moment of energy which contributes to the movement of the marble is not being considered in our calculations.

(INSERT DRAWING)

We can assume that the vertical component will be stored and dissipated as the marble travels the horizontal component. This horizontal component will gradually diminish due to surface friction on the marble, bringing it to a stop.

2. The distance the marble rolls after exit from the tube will depend on the surface over which it is rolling. A weave carpet is suggested in the write up so as to prevent the marble rolling too far on a smoother surface.

Some good questions to ask team members:

a) If the tube is placed vertically, why doesn't the marble roll horizontally? (Answer: there is no horizontal component of velocity).
b) What causes the marble to roll to a stop after it exits the tube? (Answer: Friction with the surface).
c) Why does the marble not roll as far when the tube's upper end is at a small height ***h***? (Answer: This means the potential energy, hence the resultant kinetic energy, is low—so the marble exits the tube at a low velocity).
d) Since the maximum velocity from the equation doesn't depend on the mass ***m*** of the marble, does a heavier marble roll further or not as far as a lighter marble? (Answer: The heavier marble has more momentum because of its mass, even though its velocity is the same, hence one would expect it to roll further).
e) If the tube is placed horizontally, why doesn't the marble roll down the tube? (Answer: The marble has no potential energy in this case, so there can be no kinetic energy, either).
f) If the tube were longer than 24" with the same height ***h*** of the upper end, would the marble gain more speed before exiting the tube? (Answer: No, because the potential energy is the same for the same height ***h***).
g) What about friction inside the tube—doesn't that slow down the marble as well? (Answer: Yes, and this results in the actual maximum velocity being somewhat less than the value given by the equation. Therefore, the longer the tube, the lower the exit velocity for a given height ***h***).
h) Does the diameter of the tube make a difference? (Answer: Yes, it does, because the marble also experiences friction as it moves through the air in the tube. This becomes more of a problem if the tube is only slightly larger than the marble since the air in front of the marble must get to the back of the marble by flowing through the small space between the marble and the tube. This effect in this particular experiment is very small).

NOTE: The software is available (on disk in Basic) for necessary computations.

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