

2001 MEAP Investigations

By: Annis Hapkiewicz and Dave Chapman, Okemos High School, Alex Azima, Lansing Community College

The 5th grade MEAP investigation is named the Reducing Friction Investigation. It is looking at the difference in the amount of force needed to move a book or books over a table surface by sliding the book across the table Vs rolling the book on soda straws placed under the book(s). The objectives addressed are:

Objective –elementary	Related concepts, terms, and tools	Real-world contexts
PMO 02 Describe how forces (pushes or pulls) speed up, slow down, stop, or change the direction of a moving object.	Words describing changes in motion: <i>speeding up, slowing down, turning</i> Words describing common forces: <i>push, pull, friction, gravity</i>	<i>Playing ball, moving chairs, sliding objects</i>
C 02 Develop solutions to unfamiliar problems through reasoning, observation, and/or experimentation.	Appropriate scientific concepts, terms, and tools	Appropriate scientific contexts
R 01 Develop an awareness of the need for evidence in making decisions scientifically	<i>Data, evidence, sample, guess, opinion</i>	Deciding whether an explanation is supported by evidence in simple experiments.
R 04 Describe how technology is used in everyday life.	Provide faster and farther transportation and communication, organize information and solves problems, saves time.	Cars, other machines, radios, telephones, computer games, calculators, appliances.

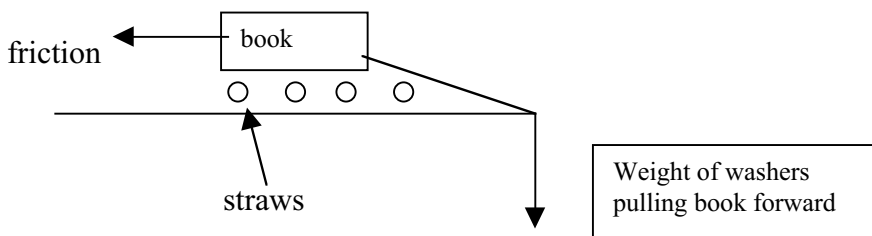
The question is “How does the use of rollers affect the force required to move a book (or books) a given distance along a surface?”

Students can be encouraged to discuss any real-world experiences they have had with rollers. Luggage carousels at airports, conveyor belts at Service Merchandise, slides at Discovery Zone and Little Caesars are all possible examples your students may mention. You may even want to mention historical use of rollers to move heavy objects before the advent of motors. Logs were placed across the desert for moving the heavy stone blocks from the Nile to the construction site for the pyramids. The rollers in this investigation are acting very much like ball bearings. If marbles or steel balls are placed under a book you can easily demonstrate that the book moves more easily.

In this case we will measure the amount of force needed by the number of washers required to start the book moving.

Some important ideas:

- (1) A force is a push or a pull.
- (2) A force is needed to change the motion of an object. Stopping a moving object, starting to move an object that is at rest, speeding up or slowing down an object all require unbalanced forces.
- (3) Students should be aware that the more massive an object is the more force is needed to change its motion.
- (4) In the absence of any unbalanced forces, once an object is in motion, it will continue in motion.
- (5) Friction is a force that opposes the motion of an object or the attempt to move an object. Friction is the force that causes objects to stop moving once they are in motion. Friction can also produce motion, as in the case of walking. Usually heat is produced as a result of friction.
- (6) Some surfaces are more difficult to move objects over. Examples include dragging a box across a carpet Vs a smooth floor. For the teacher: While in general rough surfaces have more friction, two very smooth surfaces may actually have more friction between them because of electric and molecular attractions between the surfaces (“bonding”).
- (7) Gravity is a force of attraction that pulls objects toward the earth. For the teacher: Gravity is actually a force of attraction between any two objects that depends on the mass of the objects and the inverse square of the distance between them. Gravity is the force that keeps the earth in orbit about our sun. We are closer to the earth than the sun, so we are pulled toward the earth more strongly than toward the sun. Gravity between most ordinary objects is too weak a force to notice.
- (8) We are measuring the amount of force needed to move the book(s) by the number of washers used. For the teacher: the actual force is the weight of the washers (mass \times acceleration due to gravity). Remember a force is a push or pull; the pull is caused by gravity pulling the washers downward. We can increase the force acting on the book(s) by increasing the weight (number of washers). Note: The increased weight increases the applied force *and* it also increases the total mass of the moving system.



Students will observe that more washers are necessary to change the motion of two books than one book. This is easy to explain in terms of inertia *and* the increased friction due to increased weight. The more massive an object the greater the force needed to change its motion. It is harder to stop a freight train than a car; it is harder to start a bowling ball rolling than a ping pong ball. Also, the more weight, the more contact between the books and the table, thereby increasing friction.

Students will also observe that with straws or rollers under the book less force is needed to move the book. Here the explanation becomes complicated. But since friction is the force that resists the movement of the surface of one body over the surface of another, it acts whenever one body slides or rolls over another. Friction is generally smaller when bodies roll over one another than it is when bodies slide over one another. Machines are built to minimize the rubbing of parts and ball bearings are frequently added to replace the sliding of parts against another with the rolling of the same parts. The complication is that we have different types of friction involved (1) static friction opposing the initial movement of the book (s) (2) sliding friction which is less than the static friction operates as the book is moving over the surface and (3) rolling friction. We are substituting rolling friction for sliding friction as a source of resistance to motion.

The amount of force needed to start the book moving from rest is greater than the force needed to keep the book moving always. So the amount of friction for sliding the book across the table is actually less than the force needed to initially start the book moving. Students will probably observe that the book starts to accelerate. The reason is that there is a net force pulling the book forward i.e. the force exerted by the washers is greater than the frictional force holding the book back. The number of washers used in this experiment is NOT measuring the amount of friction IF THE BOOK ACCELERATES. If the weight of the washers just balanced the frictional force the book would have to move at a constant speed.

Simple machines usually make work “easier” by reducing the force needed to move the object (ramp), changing the direction of the force (simple pulley), or multiplying the distance over which force is exerted (wheel and axle). Simple machines do not reduce friction. It is not clear that the rollers can be described as a simple machine. They are not acting as a wheel and axle. They are not doing work. It is definitely not true that they are a simple machine because they reduce friction—if this were so then I would be hard pressed to justify why grease is not a simple machine.

The original question was “How does the use of rollers affect the force required to move a book (or books) a give distance along a surface?” Students should be able to tell me that rollers reduce the force needed to move the books. The teachers guide for this investigation was printed before an error was discovered. The statement on page 10 titled “Reasons for my conclusion” should be that it is observed that it takes fewer washers to move the book when the rollers (straws) are used. The student observed the number of washers used. **The student did not observe the amount of friction.** (We want student to understand the difference between an observation and an inference!) **The rollers are definitely NOT a simple machine; this is an error in the teacher guide.** Machines

change the ratio of force and distance. Some simple machines will merely change the direction a force acts in like a simple pulley. Other simple machines will allow one to exert a smaller force over a greater distance, like an inclined plane. Others will allow one to exert a greater force over a small distance in order to move an object a longer distance, like a broom or fishing pole which are both 3rd class levers. The wheel and axle also take a large force acting on a small distance and produce a smaller force acting over a greater distance.

I would not encourage students to conclude that there is less friction or that the rollers are simple machines. But I would not try to explain all the complexities of this to elementary students. Students should understand that reducing the friction would reduce the force needed to prevent the book from stopping once we get it moving. I would ask them to tell me ways they can reduce the friction between the book and the table. Encourage them to think about lubricants, hover craft, placing shinny paper or plastic under the book, etc. I would also encourage the students to think about how simple machines can reduce the amount of force needed to move an object with real world examples of using ramps (incline planes), levers for lifting, or pulley systems. I would mention that simple machines do not always reduce the amount of force needed and mention some examples like the wheel and axle on a bicycle or I would demonstrate that a 3rd class lever (broom or fishing pole) requires more effort force than resistance force.

There are several misconceptions that the teacher will want to be watchful for in listening to the students as they do this investigation.

- (1) Naïve students may believe that constant motion requires a constant force. Students at this age should begin to understand that once an object is moving it would stay in motion until an outside force stops it. Naïve students may believe that if a body is moving forward there must be a net force in the forward direction.
- (2) Naïve students may believe that if a body is at rest there are no forces acting on it. Rest means the forces acting on an object are balanced. So if a book is on the table, gravity is pulling the book downward but the table is exerting an equal and opposite force upward.
- (3) Naïve students may believe that machines can do more work than people put in. This is impossible. If there were not friction the input work and the output work would be equal. In the real world, the input work is always greater than the output.

The 8th grade investigation is looking at the chemical weathering with acid of an earth material, calcium carbonate or chalk. Students at this level are expected to design their own experimental procedure. The objectives addressed include:

Objective- middle school	Related concepts, terms, and tools	Real-world Contexts
EG 10 Explain how rocks are broken down, how soil is formed, and how surface	Forces: <i>gravity, pressure</i> Erosion by : <i>glaciers, waves, wind, streams, weathering,</i>	Local areas where erosion by wind, water, or glaciers may have occurred, <i>such as</i>

features change.	<i>plant roots</i> Decomposition by: <i>bacteria, fungi, worms, rodents, other animals</i> See EC 10- Identify some common materials that cycle through the environment- <i>carbon cycle, water cycle</i>	<i>along the shoulder of roads, under downspouts</i> Chemical weathering from road salt; formation of caverns Physical weathering, such as <i>potholes and cracks in sidewalks from freshwater</i>
PCM 04 Describe common physical changes in materials; evaporation, condensation, thermal expansion and contraction	States of matter: <i>solid, liquid, gas</i> Changes in state of matter: <i>evaporation, condensation</i> Thermal expansion and contraction	Changes in state, such as <i>water evaporating as clothes dry, condensation on cold window panes</i> Expansion of bridges in hot weather
C0 8 Design and conduct simple investigation	Words describing the process of scientific investigations: <i>test, fair test, hypothesis, data, conclusion</i> Forms for recording and reporting data: <i>tables, graphs, journals</i>	Appropriate scientific contexts: see EG 10 and PCM 04
C 12 Write and follow procedures in the form of step-by-step instructions, recipes, formulas, flow diagrams, and sketches	Terms: <i>purpose, procedure, observation, conclusion</i>	Following a recipe Listing or creating the directions for completing a task.

The question is: “ How does the amount of vinegar in a solution affect the breakdown of chalk?”

Background:

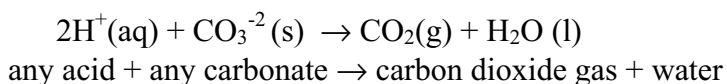
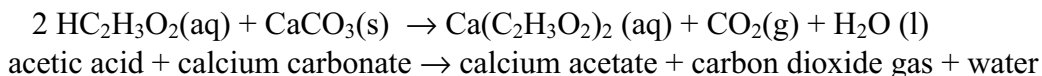
Weathering is the change in the physical form or chemical composition of rock materials exposed at the earth’s surface. There are two categories of weathering. **Mechanical weathering** breaks rocks into smaller pieces without changing its composition. This includes (a) abrasion due to collision of rocks and sand against other rocks; (b) ice wedging when water freezes in cracks and pores; and (c) burrowing animals and plant roots. **Chemical weathering** breaks down a rock by changing its chemical composition. This process includes (a) hydrolysis (reaction with water); (b) oxidation (primarily reaction with oxygen); (c) reaction with acids (from natural carbonic acid in rain, human pollutants, and acids from lichens and mosses).

Erosion, the term used throughout the MEAP investigation, is the transport of the products of weathering by natural agents (such as rivers, wind, waves, and glaciers). Sometimes this term is used to include both the process of transport and weathering together.

Vinegar is a 5% solution of acetic acid which is a weak acid. Chalk is calcium carbonate.*

*Note: not all blackboard chalk will react with vinegar. The “dustless” chalks have a coating on them that prevents their reaction with vinegar. The MEAP office had to be very careful to find a brand of chalk that would react with the vinegar for this investigation.

All carbonate salts will react with acids to give off carbon dioxide.



Many sedimentary rocks contain carbonates because the shells of diatoms and other marine animals contain calcium carbonate. As these animals die and settle to the bottom of the ocean, a layer of carbonate rich sediment builds up. Over time pressure forms carbonate rich sedimentary rocks (such as limestone) and, with additional pressure and heat, metamorphic rocks (such a marble). Calcium carbonate may also be a cementing agent in other sedimentary rocks, including shales and sandstone.

Concern about weathering and erosion of human-made structures have lead to different actions to protect them. Acidic rain in particular has caused people to (1) choose different building materials (e.g., sandstone rather than limestone or marble); (2) put up barriers (e.g., roofs over statuary); and (3) even special coatings or finishes on rock materials.

The hypothesis to be tested: “Chalk can be broken down chemically by a weak acid solution. The extent of the breakdown of chalk is directly related to the strength of the acid solution.”

The students are given 3 pieces of white chalk, 3 clear plastic cups, 200 ml of vinegar, and a plastic device calibrated in milliliters. The students are to plan and write down the procedure they will use for testing the hypothesis. They should be encouraged to design tables or charts for recording their observations. The teacher should check each student’s procedure before allowing him or her to proceed. The students will all have to investigate the same hypothesis for the MEAP because the questions on the test are designed for this particular investigation. In classroom teaching it would be preferable to allow the students to formulate their own hypothesis.