LCM Formal Loop Lesson Plan: Friction

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Standards:
Science: A6, B1
Math: E1, E3
Cultural: B1

Grade level ~ 9th

Science Concept:
Friction is a force that opposes relative motion (sliding) between two surfaces. The size of the friction force is (nearly) independent of the surface area of contact. The size of the friction force between two surfaces is proportional to the force with which the two surfaces are pressed together. The nature of the surfaces in contact can also affect the size of the friction force.

New Vocabulary:
Normal Force
Friction

(timeline: 2 – 3 class days)

Activity	Process Skills	Materials
Gear up: Review what we've been doing: Newton's 1st and 2nd Laws of Motion. (1st Law - If **Fnet** = 0, then **a** = 0. If **a** = 0, then **Fnet** = 0. Review 2nd Law and point out that 1st is special case of 2nd.) Explain that we'll be looking at Newton's 3rd Law in a few days, and that it talks about what forces are. Say, "But today, we are going to look at a particular type of force that is very important. Without this force, standing on the floor here, I would not be able to start to walk across the room, or having started walking across the room, I wouldn't be able to easily stop. In your car, you wouldn't be able to start in motion down the road, or, once in motion, be able to safely stop. This force makes driving your car more expensive - much of the gasoline you put in your engine is spent in overcoming this force - but without it your car wouldn't run. Millions of dollars are spent each year on efforts to reduce the effects of this force, or, in some cases, to make this force greater. What force am I talking about?" (Student response: "friction") Define **friction**. (Friction = a force which resists two surfaces sliding past each other.) Differentiate friction from other resistance forces which oppose or hinder motion - air drag or other fluid drag. Emphasize that we will use the word friction ONLY to talk about this resistance between two surfaces, not for fluid drag.	classifying	

Activity	Process Skills	Materials
Explore: Ask students to experiment with a book or other object on their desk. Ask them how much the friction force is if it requires 2N of force to push the object at a constant speed. Go over / have them go over 1st Law analysis that says **Fnet** = 0, →Friction = 2N → If they push at constant speed, their push is equal to force of friction. Ask them to experiment with the object to see what kind of things they can do to change the friction they have to push against.	Observing Investigating	book or other object
Generalize: Field student responses about what could affect the size of the friction force, and list them on the board. You should be able to expect each of the following responses: Weight, surface area, nature of surface, speed. You should be able to get them to modify the response "weight" to express the idea that it is instead the force pushing the two surfaces together, or the force with which they push apart which matters. Give this force the name Normal Force (only so that the students don't have to write down the whole phrase every time they talk about it. Emphasize that they should only substitute the name for the idea if they remember what it means. The name doesn't substitute for the understanding.) You should further get them to clarify that it's the nature of BOTH surfaces that matters, not just one or the other. If students don't come up with any of these expected responses you can probably elicit them from the students, or supply them depending on how things are going. Other things which they may come up with that could affect the friction force include: lubrication, temperature, orientation/shape, pulling angle, and temperature. You may or may not want to make sure to get these things included in your list.	Hypothesizing	

Activity	Process Skills	Materials
Experiment: I have the students conduct this rather commonplace friction experiment on a large scale. Rather than pulling small lab weights across the table, they pull each other around the room on a rug. They need to measure their weights using a bathroom scale I have modified to read in Newtons. They pull using a large fish scale which goes up to 100kg to pull the rug. (This scale has also been modified to read in Newtons.) If you chose not to modify your scales, you could use ordinary scales and convert to Newtons. The rug I use is about 4' by 4'. It has a 2X4 stapled the length of one end. A rope bridle is attached to this 2x4, and then a short length of rope - perhaps 4 ' - is tied to the bridle. The fish scale is then clipped with a carabiner to a loop in the end of this towline. Two 2'X4' sheets of 5/8" to 3/4" plywood are placed on top of the rug to provide a platform for the students to sit on. The rug may be folded in half with both boards stacked on top of it, or the surface area may be doubled by unfolding the rug and placing both boards on it side by side. Bicycle helmets would be an additional useful safety precaution. Alternatively, this experiment could be performed on a smaller scale, with lab weights, but the large scale kinesthetic aspect adds to student learning and to their enjoyment of this lab. Identify the normal force as the variable of interest in our experiment, while students will also be taking some data to look qualitatively at the effect of surface area. Have them work at filling out their experiment report forms. I have them address some specific points in their hypothesis; "What is the correlation between friction and the normal force? What will the graph of friction vs. normal force look like? What effect will increasing the surface area have on the friction?" They should be able to identify the ideas they developed in the generalize step as their controls. Once they have had a chance to finish their hypotheses, split the class in half. Tell them that in addition to seeing the effect of normal force on the friction, each half will be using a different surface area in contact, and then graphing both sets of data on the same paper. Demonstrate the experiment set-up. Discuss how you will need to pull (constant speed at a low angle) for the spring scale reading to be the same size as the friction force. Show how they will change the surface area.	Hypothesizing Controlling variables Predicting Investigating Experimenting Collecting data measuring	➢ bathroom scale (preferably modified to read in Newtons) ➢ large capacity fish scale (also modified to read in Newtons) ➢ ~ 4' towline, with an eye in one end for clipping to the fish scale ➢ carabiner ➢ ~4'X4' carpet remnant, with 2X4 attached the length of 1 edge, with a towing bridle attached to the 2X4 ➢ 2 ~4'X4' pieces of ~5/8" plywood to serve as a platform to sit on.

Activity	Process Skills	Materials
Have the students write as their special notes, either; "We used one," or, "We used two boards." Then the 2nd group can be put to work on another assignment. I usually have them finishing the previous day's lab on pressure , and have a bookwork assignment for them to work on. The first group I pull over and give a couple of the students direct instructions for the lab. I pick someone I expect to be responsible - usually a girl, as they will have the easiest time getting the boys to do what they say - and put that person in charge. I explain that they want to get a good range of data, and so that they should increase the weight by pulling first the empty board, then a small person, then a big person, then 2 small people, a big and a small person, 2 big people, 3 small people, and so on, to complete their data table. They are responsible for deciding who is to get on the scale, for getting their weights, for adding the weights up, and for making sure the data is collected. I take another student aside - generally one of the larger students, as they will be able to pull the best without slipping - and have them be in charge of the scale. I show them the particulars of working with the scale so that they get the readings in Newtons, and so that the scale doesn't lose it's zero. I remind them that they have to pull at the same (constant) speed through the whole experiment, and that they need to take the measurement while they are moving at constant speed. We take the first piece of data together, for the empty board. I tell people that they should take the data sitting down, and that they do need to pull slowly, as safety precautions. Bicycle helmets wouldn't be a bad idea. After that I am free to monitor the classroom, and just need to check back in with them occasionally to make sure that they are getting good data in a timely fashion. Each group should be able to get their data in 15-25 minutes. If you have enough time to spend on it (and more activities), you could break the class into smaller groups, and have each do a different surface area.		

Activity	Process Skills	Materials
Interpret: The collected data is posted on the board for the students to copy and graph. Students are instructed to make a different symbol for one board vs. two boards for the data points on their graphs. Students should write conclusions to their lab report forms making sure in particular to address the points asked for on the conclusion sheet. They should base these conclusions on their experimental graphs. These graphs should show direct proportionality between the friction and the normal force, and no correlation between friction and surface area. Ask students what the slope of the graph means - what for instance it would say about the surfaces in question if the graph had a steeper or a shallower graph.	Making graphs Interpreting data Inferring Communicating Generalizing Making mathematical models	
Apply/Assess: Students should be able to accurately report the results of their experiment, addressing some specific points in their conclusion. Students should be able to answer questions about which of the following would be possible ways of increasing friction between the tires of their car, and the road; increased tire width with the same tread pattern; using a different type of rubber; using a different tread pattern; and putting sandbags over the drive wheels.	Predicting Generalizing Using mathematical models	
Extensions: Possible extensions to this experiment include activities to explore the effect of speed, lubrication, or the type of surface on the friction. An experiment about the effect of speed on friction could be run very similarly to how this experiment was run. Students could perform meaningful experiments to test the friction achieved with different types of tires or with different highway conditions. In addition to or instead of doing these as student experiments, you could look at these things as qualitative demonstrations in class. Another useful extension is to move from the slopes of the graphs to tabled values of the coefficients of friction for various surfaces. Another extension is to have students discuss why Indy cars have the spoilers / airfoils over the rear of the car and over the front wheels.	Predicting Generalizing Using mathematical models Measuring Experimenting Hypothesizing Making graphs	

Friction Lab conclusions should include: (These **MUST** be in complete, self-explanatory sentences).

- Did the data support your hypothesis? Explain. (Did your graph show friction to be proportional to the weight)?
- What was the slope of your graph (complete with units). (In the data section, show me your calculations of the slope - complete with units).
- What is the meaning of the slope? That is, what does it say about the friction between the two surfaces? Another way to think about this, is, if the surfaces were “stickier” - say, rubber instead of carpet - what effect would this have on the slope?
- Based on how the other group’s data compares to yours, how does the surface area of contact between two surfaces affect the friction between the surfaces?
- Does friction act in the direction of sliding or in a direction to oppose sliding?

Lab Scoring Guide

Experiment

_________ **Technique**

methods chosen demonstrate forethought
effort made to limit effect of controls
procedure shows care and attention to detail

Report

_________ **Title**

not excessively wordy
identifies what experiment is about

_________ **Purpose**

independent and dependent variable identified
ALL questions being investigated identified

_________ **Procedures**

important details sufficiently explained; trivial details omitted
reader provided with sufficient details to recreate experiment

_________ **Variables/Controls**

independent and dependent variables properly identified on fo
proper units supplied for independent and dependent variable
important controls listed

_________ **Data Table**

columns headed with variable names
units given in column headings
sufficient data are gathered to demonstrate phenomena

_________ **Graph**

axes titled with variable names, units in ()
independent variable on horizontal axis
numbering system uniform, starts at (0,0)
numbering system goes up by 1's, 2's, 2.5's, 5's, etc.
data occupies over 1/2 the graph
data points plotted accurately
data points fitted with point protectors
best-fit line shows trend of data, if trend observable
best-fit line DOESN'T zig-zag to connect the dots
for straight best-fit lines, slope is calculated (with units)
slope taken from points on best-fit line, work shown

_________ **Conclusion**

results are interpreted in relation to stated purpose
identifies if results support hypothesis and explains how
does NOT say hypothesis was "correct" or "incorrect"
explains slope
answers any asked-for questions specific to this lab

_________ **Conventions**

written in complete, self-explanatory sentences
spelling and grammar correct
neat

_______ **OVERALL SCORE**