EFFECT OF VISCOUS DRAG ON SMALL SPHERES FALLING THROUGH LIQUIDS

TOPIC:

Fluid Friction

SCIENTIST:

George Stokes 1819–1903

INTRODUCTION:

Friction is the name given to a force which opposes the sliding motion of two surfaces in contact with each other. We see friction in action every day: the soles of our shoes stop us sliding on a polished floor; brake pads or disks enable a car to stop. However, friction also exists in fluids (liquids and gases). Ships moving through water and aircraft moving through air both experience fluid friction, or "drag" as it is better known. This explains why ships, aircraft, and automobiles are designed in such a way as to reduce drag to a minimum. George Stokes was one of the first scientists to investigate fluid friction. He looked at the effect of drag on small spheres falling through liquids. It was already known that objects falling in a vacuum accelerate constantly. Stokes showed that although the spheres accelerate to start with, they soon reach a constant velocity and accelerate no further. He explained that this is due to the upthrust of the liquid and the drag of the liquid. Both of these forces act upwards, preventing a sphere from accelerating further so that it reaches a uniform, terminal velocity.

TIME NEEDED:

1 hour

MATERIALS:

Note: You will need a partner for this experiment.

- Plexiglas® tube 1 m long, 5 cm diameter
- stopper to fit end of Plexiglas® tube
- 1 liter glycerine (from a pharmacy)
- 4 narrow rubber bands that fit tightly around the Plexiglas® tube
- watch or clock with second hand
- meter ruler
- 2 ball bearings, pieces of copper shot, or stainless steel BBs, one 0.2 cm diameter, the other 0.5 cm diameter
- glass tube 5 cm long, 1 cm diameter
- tweezers
- small dish
- ring stand with clamp
- calculator
- marker

Original Materials:

Stokes used a similar apparatus but with a number of different liquids and more ball bearings of different masses.

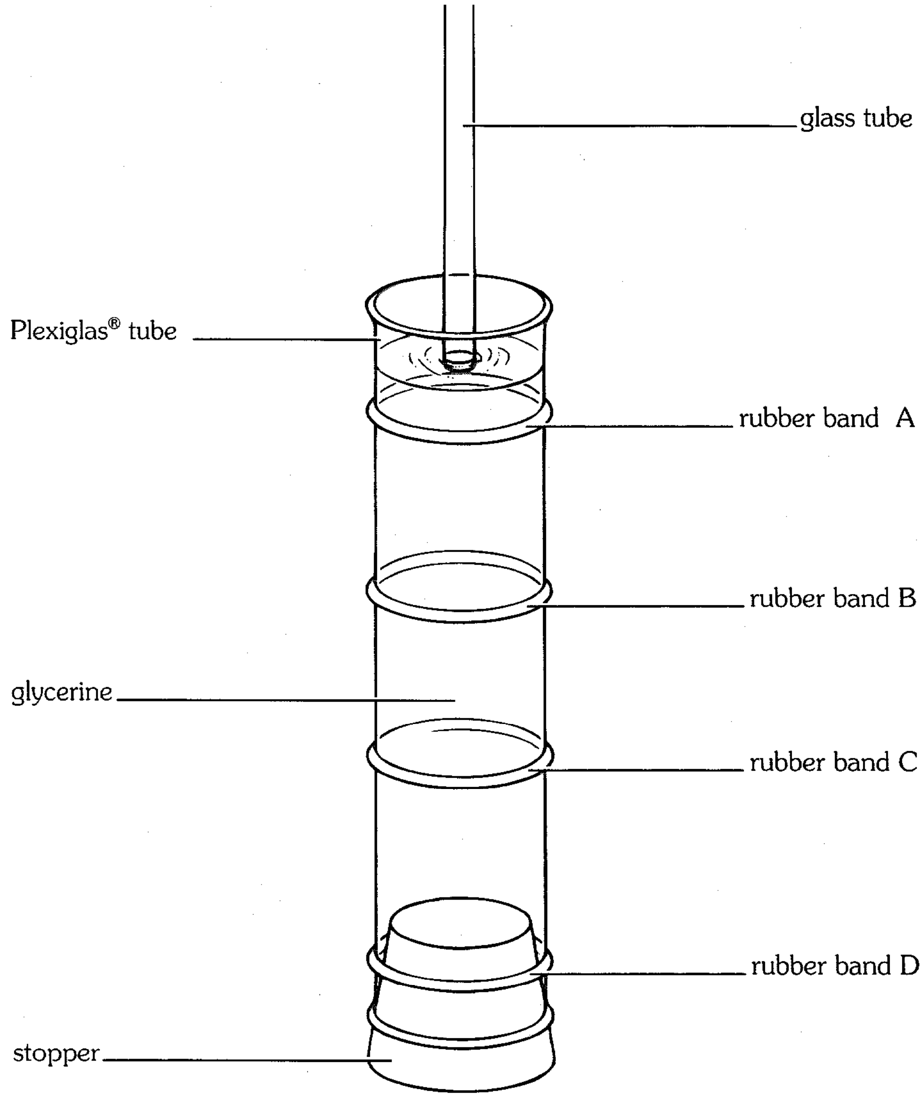
Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Take the Plexiglas® tube and fit the stopper securely into one end of it.
2. Put one rubber band around the tube approximately 3 cm from its open end. Put a second approximately 2 cm from its closed end.
3. Measure the distance between the two rubber bands and divide it by 3. Using this information, position the third and fourth rubber bands so that they are the same distance from each other and from the other two rubber bands. Mark the four rubber bands A, B, C, and D from open end to closed end (see figure 1).

Figure 1



4. Clamp the tube in an upright position on the ground with the open end up.
5. Fill the tube with glycerine to within 1 cm of the top. Pour a little glycerine into the small dish.
6. Position yourself, with the watch or clock, so that you are facing the tube.
7. Tell your partner to hold the small glass tube upright so that one end of it is just immersed in the glycerine at the center of the top of the Plexiglas® tube (see figure 1).
8. Ask your partner to pick up the small ball bearing with the tweezers, wet it in glycerine in the small dish, and then drop it down the glass tube.
9. As soon as the ball bearing passes rubber band A, start the clock or watch. In the Data Table, record the time shown by the clock or watch as the ball bearing passes rubber bands B, C, and D.
10. Repeat steps 8 and 9 with the larger ball bearing.

DATA TABLE

	Smaller ball bearing	Larger ball bearing
Time at band A	0.00	0.00
Time at band B		
Time at band C		
Time at band D		
Time taken (seconds) to travel from:		
A → B		
B → C		
C → D		

ANALYSIS:

1. Calculate the time taken in seconds for the smaller ball bearing to travel from A to B. To do this, subtract the time at band A (in this case 0.00) from the time at band B. Record your result in the appropriate part of the Data Table. Now calculate the time taken from B to C, and from C to D for the smaller ball bearing, and repeat all the calculations for the larger ball bearing. Record the results in the Data Table.
2. Describe any differences in the time taken for the smaller ball bearing to travel from one band to the next.
3. Describe any differences in the time taken for the larger ball bearing to travel from one band to the next.
4. Were there any differences between the results you described in your answers to questions 3 and 4?
5. Do some research to explain the results you found in this experiment.

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO EXPERIMENTERS

Each experiment includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are performing the experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each experiment you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:

—Clear all surfaces before beginning experiments
—Read the instructions before you start
—Know the hazards of the experiments and anticipate dangers

PROTECTING YOURSELF:

—Follow the directions step-by-step; do only one experiment at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Don't use your mouth to pipette; use a suction bulb
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not use reflected sunlight to illuminate your microscope
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES