Student's Name Kerry Kuehn   Date Aug 21, 2007 33

Subject The Vacuum   Instructor's Name Kerry Kuehn

Reference: Galileo's Dialogues, Sec. 1-73

- Introduction

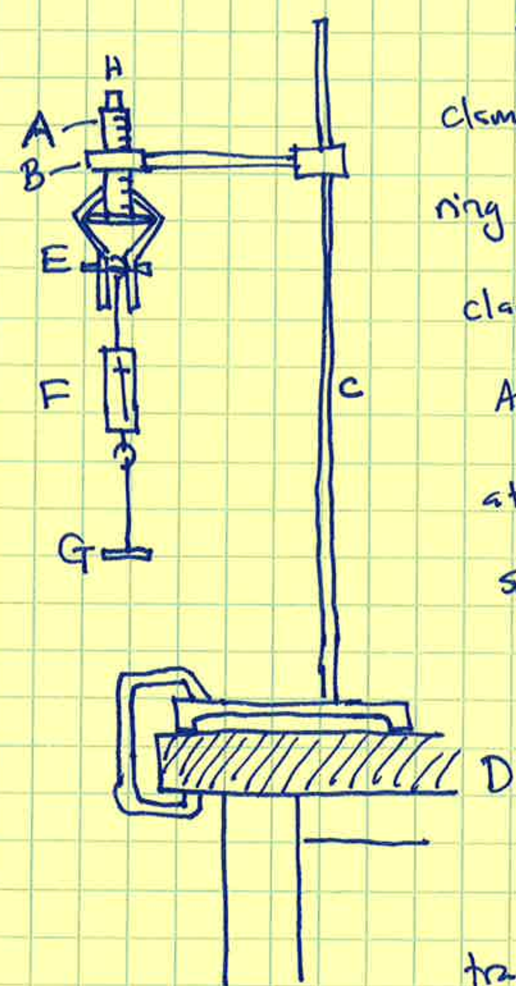
In this set of lab experiments, I will explore the cause of the coherence of bodies. Galileo suggests two possible causes (Sec. 59), these being the "repugnance which nature exhibits towards a vacuum" and the existence of "a gluey or viscous substance which binds firmly together the components of the body." The question which Sagredo (in Galileo's dialogues) raises is whether the vacuum alone might be able to account for the resistance to separation displayed by bodies such as stone or metal.

My goal will be to measure the strength of the force which holds objects together which is due to the vacuum alone. Like in Salviati's experiment (Sec. 61) I will use a substance (water) which exhibits no resistance to separation except that which is caused by a vacuum. I will use a modified form of the apparatus shown in Fig. 4 (Sec. 62)

Student's Name Date

Subject Instructor's Name

Apparatus Diagram



A syringe (A) is hung from a clamp (B) which is attached to a ring stand (C). The ring stand is clamped to a lab table (D). A test tube holding clamp (E) is attached to the plunger of the syringe. From this clamp an Ohaus 72oz spring scale (F) is hung, which records the weight which is placed on the 50gram weight tray (G). A plug (H) can be used to seal the syringe after it is filled with water. By hanging various weights from the plunger by placing them on the weight tray, I can measure the weight required to "break" the water apart and produce an empty region (vacuum) inside the syringe.

Student's Name Date

Subject Instructor's Name

First experiment

I found that a certain amount of weight was required to get the plunger to fall even when the cap was removed. This is due to the friction between the plunger and the walls of the syringe. The solution was to spread a bit of Dow Corning Vacuum Grease on the plunger to lubricate it. Now the plunger descends even when no weight is placed on the tray.

To prepare my experiment, I turned the syringe upside down and drew water into the syringe (DI water). I tapped it & depressed the syringe while upright to remove any air. I then capped it and situated it as depicted in my apparatus diagram shown on pg. 69.

The 12 c.c. syringe was filled with 2.3 ± 0.2 cc of water. The diameter of the plunger is 1.53 ± 0.02 cm (measured using calipers).

Student's Name Date

Subject Instructor's Name

Expt 1 data

Weight (oz)	Volume (c.c.)	observations
0 ± 1 oz.	2.2 ± 0.1	plunger stationary
6	↓	
13		
20		
27		
35		
42		
45	↓	
52	2.3	small bubbles forming
60	↓	
63	2.4	
70	2.6	bubbles getting larger
70+200g	2.8	plunger slowly descending & bubbles rising
63	2.6	removed some weight
70	2.8	
70+200g	4.4	Plunger slipped down as water "broke"
28	2.3	remove weight; vacuum disappears

Student's Name Date

Subject Instructor's Name

Expt 2 Use 35mL syringe, 2.30 cm dia. plunger

Weight (OZ.)	Volume (c.c.)	Observation
28	7.0	Plunger stationary
45	↓	
63	↓	
63 + 500g	↓	
" + 1000g	↓	
" + 1500g	↓	
" + 2000g	7.1	Small bubbles forming
" + 2500g	↓	
" + 3000g	7.5	Larger bubbles forming
" + 3500g	24	Water "broke" abruptly.
63	7.1	
63 + 2000g	7.2	
" + 2500g	7.5	
" + 2700g	↓	
" + 2900g	↓	Syringe is slipping in the clamp.

Student's Name　　　　　　　　　　Date

Subject　　　　　　　　　　Instructor's Name

Expt 3　Use glass syringe, 10 cc., dia. = 1.450 cm

Weight (g)	Vol (c.c.)	Obs
50	1.6	
150	↓	
250		
350	1.6	
450		
550		
650		
750	↓	bubbles
850	1.7	
950	↓	
1050	↓	
1150	1.8	
1250	↓	Very slowly descending
1300	↓	
1350	1.9	
1400	↓	large bubbles
1450	↓	
1500	2.0	

Wgt (g)	Vol (c.c.)	Obs.
1550	2.1	
1600	2.2	
0	1.7	remove weight
775	↓	
1275	1.8	
1475	1.9	
1575	2.1	
1625	2.2	
1675	2.4	moving slowly
1725	3.0	
1775	3.8	falling more quickly
0	1.7	remove weight

Student's Name Date

Subject Instructor's Name

Expt 4   glass syringe (2.5 c.c.)   dia. = 0.730 cm

Weight (g)	Vol (c.c.)	Obs
0	0.455	
50	↓	
150		
250		
300	0.500	
350	↓	
400		
450	0.550	
550	↓	
600	0.750	

Analysis

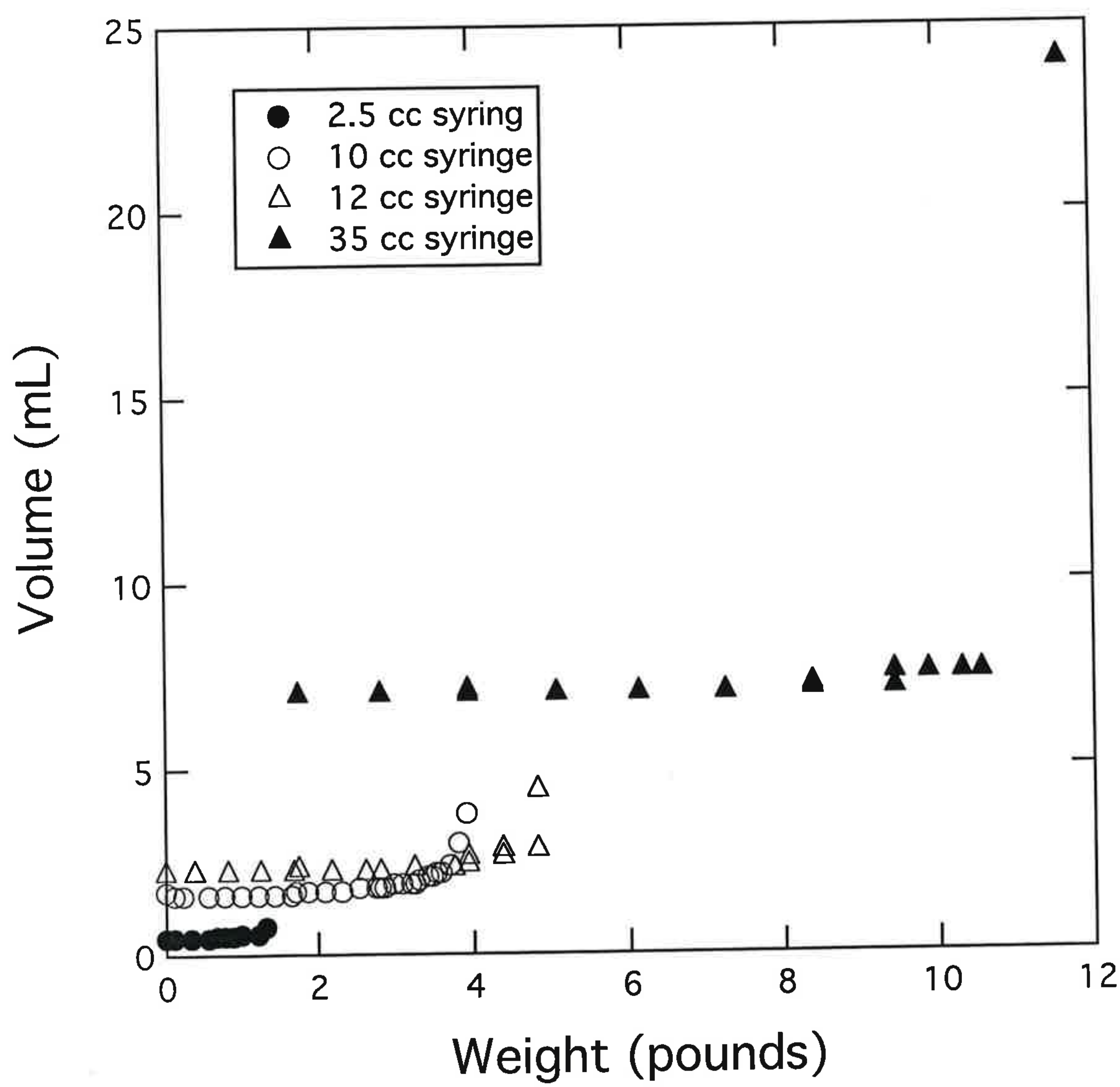
Since I have ~~been~~ been using mixed units, I need to observe some conversion factors. I will convert all of my weights into pounds.

1 lb = 453.6 grams

1 inch ~~cm~~ = 2.54 cm

I need to figure out how to analyze my data.

First, I plotted the volume of the syringe as weight was added. This is shown in the figure below for all four syringes tried. I noticed that as the size of the syringe increased, the weight required to "break" the water was also increased. Is there a mathematical relationship between the size of the plunger and the breaking weight?



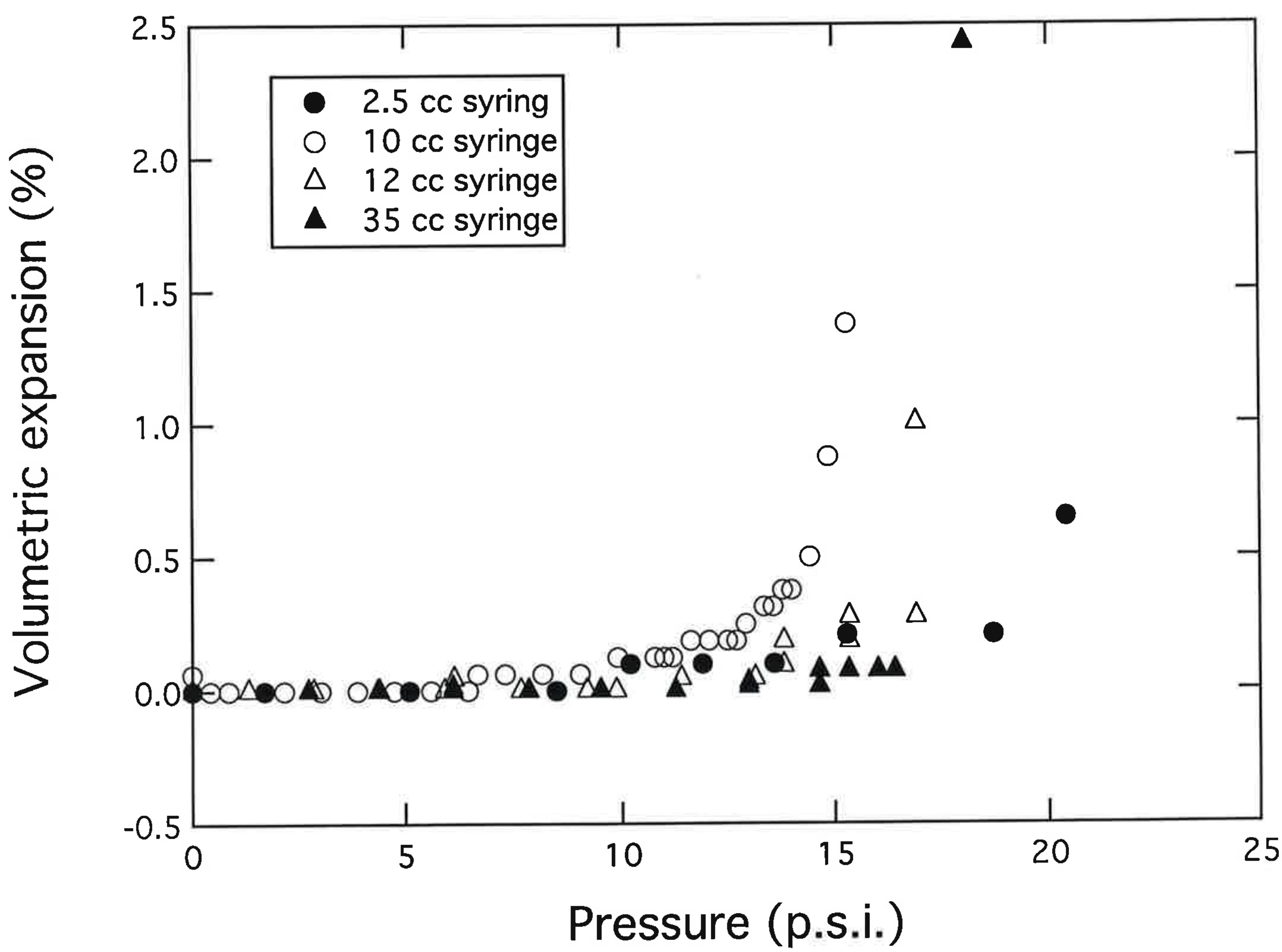
I fist calculated the % volumetric expansion from the volume using a formula

$$(\%\ \text{expansion}) = \frac{\text{Volume} - \text{Initial Volume}}{\text{Initial volume}}$$

. Then I calculated the pressure by dividing the weight by the area of the plunger

$$P = \frac{\text{weight}}{\pi R^2}$$

. Then I plotted % expansion vs pressure. It seemed that the water broke at about 15 or 16 p.s.i.



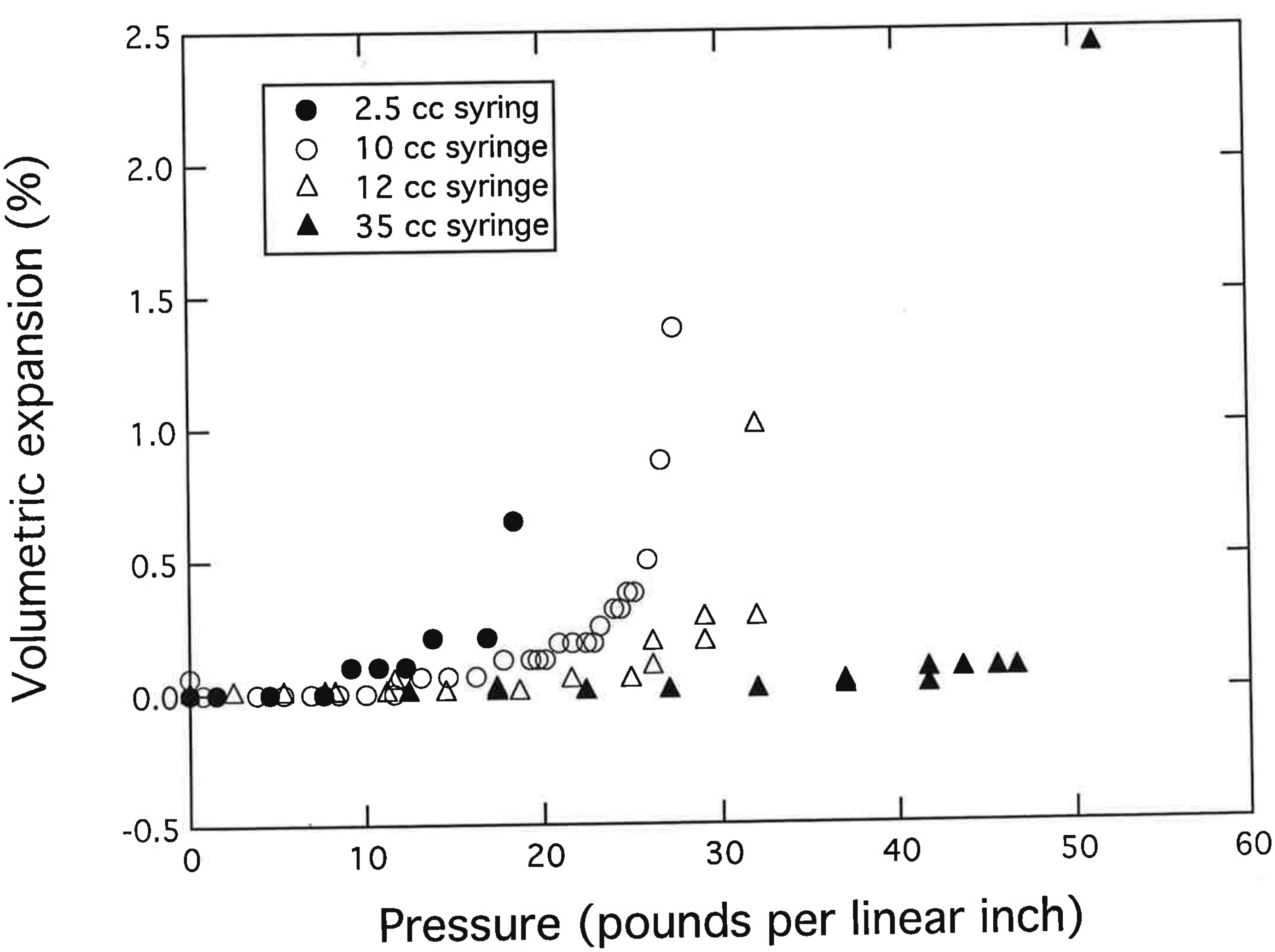
Student's Name Date

Subject Instructor's Name

To see if I got better results, I calculated the pressure in pounds per linear inch $P = \frac{\text{weight}}{\text{diameter}}$

The results showed a systematic increase in breaking pressure with increased piston size, which was not the case when I used Pressure $= \frac{\text{pounds}}{\text{square inch}}$.

It seems therefore that the strength of the vacuum is approximately 16 ± 3 p.s.i.



Any material which requires more than this amount of pressure to break apart by pulling would then need to have an additional source of resiliency, besides that produced by natures "abhorrence of vacuum.".

Uncertainty in this data arose from, primarily, uncertainty in deciding how to define when the water truly "broke". When small bubbles form? When it slides down quickly? Also, even though we used lubricant, there is still surely a bit of friction which is exerted on the plunger from the walls of the syringe. This would cause us to slightly overestimate the breaking pressure. Consequently, our results seem consistent with the measured atmospheric pressure of 14 pounds per square inch.

What causes this pressure? And how might it vary with altitude? These would be interesting experiments to perform in the future.