Thermal Expansion of Water

Physics 123 Section 2
12/12/01

Objective: Verify experimentally that water has a maximum density at 4^0C and use the data collected to compute the Average Coefficient of Expansion for water.

Materials:

Super glue
Duct tape
Empty 2-liter soda bottle
Digital thermometer
Clear straw
Saran rap
Snow
Tap water
Nail
Large pot
Measuring cup
Funnel
Eyedropper

Description:

We measured the volume of a constant mass of water measured at different temperatures. To do this we obtained an empty 2-liter bottle. Then using a hot nail poked a hole in the lid just big enough to allow the thermometer probe wire, and the straw to fit through. We duct taped these materials to the lid and saturated all possible places were after could leak with super glue. Finally we allowed this to dry for over 24 hours. After the lid was dry we then went to work on getting our water sample to 0°C. We cooled water to 0°C. To do this we made use of snow. Mixing the water with pure snow in a pot we obtained the desired temperature. Next we transported the water to the 2-liter water using a measuring cup and funnel. Then we screwed the lid on tight and filled the thing up three quarters of the way up the straw through using an eyedropper. Finally we covered the end of the straw with saran rap to discourage any loss of water through evaporation. Now with the apparatuses assembled and filled with freezing cold water we marked the starting water level on the straw and made subsequent marks on the straw at every tenth of a degree increase in water temperature. Once this data was collected we then analyzed and graphed our results.

Expectations: To see water's density peak at 4.0^0 C and a value of 1.0000 g/cm^3, meaning the water in our straw would be at it's lowest point there. Had this occurred we would have had a experimental Average Coefficient of Volume expansion of: $ß=(V_f-V_i)/ V_i(T_f- T_i) = 2.50x10^{-5} (^0C)^{-1}$ from 0^0-4^0C and $2.13x10^{-5} (^0C)^{-1}$ above 4^0C.

Results: A peak density of 1.0004 g/cm^3 occurred at 5.4^0 C.
(shown in red of graph)
A $ß=9.29x10^{-5}$ from 0^0-4^0C and $3.65x10^{-5}$ above 4^0C

Difficulties:

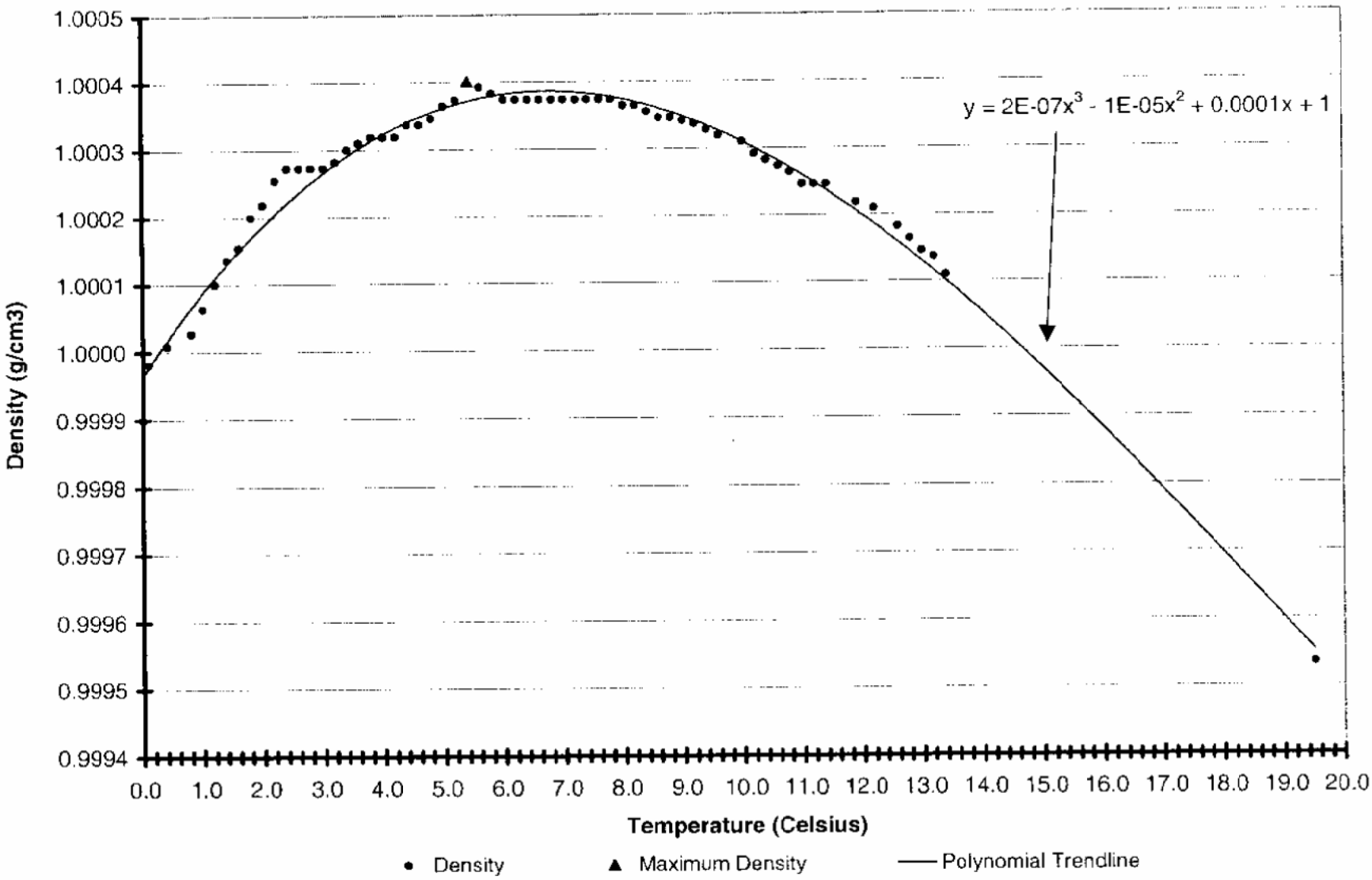
The first main difficulty we encountered was to find a thermometer, which read to the first decimal place. We ended up having to buy an expensive digital thermometer. The first time we did the experiment the lid leaked where the straw and probe were connected. To fix this we used lots of superglue. Then we tried again but the lid itself leaked. So we ditched that container and used a 2-liter soda pop bottle. Using this bottle again the lid leaked where the straw connected to it. Again we used lots of superglue. With this fixed we again began the experiment. We got the water to zero and decided to put some ice in the bottle so that the temperature wouldn't drop before we could get the lid on and ready to begin taking measurements. But the opening of the bottle was not big enough to get any of the ice back out of the water. We thought we could just wait until the ice melted but after waiting several hours the ice still wasn't melted. So we started over again this time not putting any ice in the bottle.

Sources of Error: Both Human and Mechanical error account for the discrepancy in the results. Water always evaporates and to prevent loss of water due to evaporation we put saran wrap on the top of our straw. We did not remember to do so until the experiment had already begun. Some water was lost to evaporation despite we were still at fairly low temperatures before putting wrap on. Our original plan was to see the density change all the way to 100^0 C. To help the water change temperature more quickly we tried to use a blow-dryer. Surprisingly, the water level in the straw began dropping quickly whenever the blow-dryer was turned on. We tried to use it from different angles and distances but the same result occurred, so we abandoned that idea. Then we decided if we put the 2-liter bottle in a water/ steam bath we could warm it up faster. A water bath would put increased pressure on the bottle and because it was not rigid that would affect the results. Placing the bottle in the steam bath caused the same effect in the straw that the blow dryer did, so we stopped and decided to let it warm up at room temperature. Due to time constrains we could only collect data under observation until 13.4^0 C. The last data point was taken hours later when we returned home.

The digital thermometer read the water temperature to the nearest tenth of degree using a probe. Because was quite small compared to the volume and while we considered the temperature to be uniform throughout the system, that was not the case. We had no way of making sure it was uniform or taking a more accurate temperature of the system as a whole. Our straw ended up being too short. As the temperature approached room temperature, the water level reached the top of the straw. It would have been better to have a more rigid container

Ideally we should have run the experiment a couple of times. Not knowing how to increase the rate of the water's temperature change without disrupting our results we didn't have the hours to spare in observation. On a second trial though saran wrap would be in place at the start and the bottle would not be handle so much. No blow-dryers either. One other error, we did not mass the water. The mass we used to calculate the density was found by using the density value for water at 0^0 C (given in book) and our initial volume reading. Had we taken the mass ourselves the density might have remained at 1.0000 and under.

The Thermal Expansion of Water: Density vs. Temperature



Temperature	Density	Vol	Height	Height Adjusted
0.0	0.9999	2152.85	14.10	14.50
0.1	1.0000	2152.67	13.20	13.60
0.4	1.0000	2152.61	12.90	13.30
0.8	1.0000	2152.57	12.70	13.10
1.0	1.0001	2152.49	12.30	12.70
1.2	1.0001	2152.42	11.90	12.30
1.4	1.0001	2152.34	11.50	11.90
1.6	1.0002	2152.30	11.30	11.70
1.8	1.0002	2152.20	10.80	11.20
2.0	1.0002	2152.16	10.60	11.00
2.2	1.0003	2152.08	10.20	10.60
2.4	1.0003	2152.04	10.00	10.40
2.6	1.0003	2152.04	10.00	10.40
2.8	1.0003	2152.04	10.00	10.40
3.0	1.0003	2152.04	10.00	10.40
3.2	1.0003	2152.02	9.90	10.30
3.4	1.0003	2151.98	9.70	10.10
3.6	1.0003	2151.96	9.60	10.00
3.8	1.0003	2151.94	9.50	9.90
4.0	1.0003	2151.94	9.50	9.90
4.2	1.0003	2151.94	9.50	9.90
4.4	1.0003	2151.90	9.30	9.70
4.6	1.0003	2151.90	9.30	9.70
4.8	1.0003	2151.88	9.20	9.60
5.0	1.0004	2151.85	9.00	9.40
5.2	1.0004	2151.83	8.90	9.30
5.4	1.0004	2151.77	8.60	9.00
5.6	1.0004	2151.79	8.70	9.10
5.8	1.0004	2151.81	8.80	9.20
6.0	1.0004	2151.83	8.90	9.30
6.2	1.0004	2151.83	8.90	9.30
6.4	1.0004	2151.83	8.90	9.30
6.6	1.0004	2151.83	8.90	9.30
6.8	1.0004	2151.83	8.90	9.30
7.0	1.0004	2151.83	8.90	9.30
7.2	1.0004	2151.83	8.90	9.30
7.4	1.0004	2151.83	8.90	9.30
7.6	1.0004	2151.83	8.90	9.30
7.8	1.0004	2151.83	8.90	9.30
8.0	1.0004	2151.85	9.00	9.40
8.2	1.0004	2151.85	9.00	9.40
8.4	1.0004	2151.87	9.10	9.50
8.6	1.0003	2151.88	9.20	9.60
8.8	1.0003	2151.88	9.20	9.60
9.0	1.0003	2151.89	9.25	9.65
9.2	1.0003	2151.90	9.30	9.70
9.4	1.0003	2151.92	9.40	9.80
9.6	1.0003	2151.94	9.50	9.90
10.0	1.0003	2151.96	9.60	10.00
10.2	1.0003	2152.00	9.80	10.20
10.4	1.0003	2152.02	9.90	10.30

10.6	1.0003	2152.04	10.00	10.40
10.8	1.0003	2152.06	10.10	10.50
11.0	1.0002	2152.10	10.30	10.70
11.2	1.0002	2152.10	10.30	10.70
11.4	1.0002	2152.10	10.30	10.70
11.9	1.0002	2152.16	10.60	11.00
12.2	1.0002	2152.18	10.70	11.10
12.6	1.0002	2152.24	11.00	11.40
12.8	1.0002	2152.28	11.20	11.60
13.0	1.0001	2152.32	11.40	11.80
13.2	1.0001	2152.34	11.50	11.90
13.4	1.0001	2152.40	11.80	12.20
19.5	0.9995	2153.63	18.10	18.50