Determining the Force of Water drag on different Swimming Positions

by

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Purpose:

To examine different swimming forms and determine the differences in water friction and measure the deceleration. We presume that water friction will react similarly to the way air resistance will work.

In air and in water, resistance is the reason an object slows down. Resistance is determined by the surface area of the object opposing the motion. For example, a person falling with a parachute falls much more slowly than a person without a parachute does. This is true because the person with the parachute has more surface area opposing the motion. Therefore we can conclude that he/she has more resistance. In this lab we hope to conduct a similar experiment underwater and determine which swimming form has more resistance.

We will be analyzing the motion of a swimmer after a pushoff and the affects that different body positions have on the motion. Using data obtained from our movies we will model the position data with equations which describe the motion.

From our project we hope to determine which of three swimming positions, after coming out of a turn, will reduce the drag force of water on the swimmer the most. In addition we hope to determine the way in which water drag affects the swimmer. Is the force of water drag constant or is it velocity dependent and not a constant value. Going into this experiment I am guessing that the drag forces on the swimmer will be velocity dependent and not a constant value.

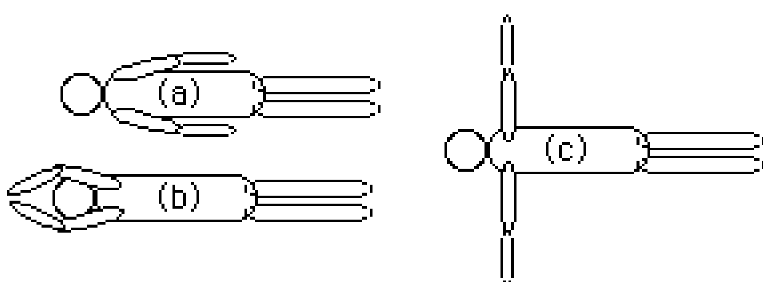


Figure 1: the three swimming positions that we will analyze.

Theory:

To calculate the force of water drag acting on the swimmer we first had to determine the way in which this force acts. Either the force of water drag is a constant value or it is velocity dependent and changing as the swimmer's velocity changes. Taking into account what is know about water drag I can say that it would only make sense that the force of water drag is dependent on velocity. Under this assumption the force of water drag is greatest when the swimmer's velocity is greatest.

Using the computer to analyze the swimmers motion we will come up with position data. We can use this data to find a model equation for the motion. Here we must decide which way we will model our position data. If the force of water drag is constant we simply fit a second-degree polynomial equation to our position data found in video point. Our position equation would be as follows:

$$X = at^2 + v_0 t + x_0$$

From this equation a constant value for acceleration can be found. With acceleration, a constant value for the force of water drag can be obtained using the equation:

$$F_{waterfriction} = ma$$

After reading about drag forces I have come to the conclusion that the previous method, in which we found the force of water drag to be constant, is false and does not apply to our situation. Instead, I believe that our swimmer either undergoes form drag or viscous drag in which the force due to the water drag is dependent on velocity. Viscous drag allows us to describe force using the equation:

$$\vec{F}_{DX} = -\tfrac{1}{2} C \rho_w A_{swimmer} V \hat{x}$$

where C is the drag coefficient, ρ is the density of the medium, A is the cross sectional area of the swimmer, and V is the velocity.

The equation for force under the assumption that the swimmer undergoes form drag is similar to the previous equation with the exception that velocity is now squared. The equation is as follows:

$$\vec{F}_{DX} = -\tfrac{1}{2} C \rho_w A_{swimmer} V^2 \hat{x}$$

In fluids, density and viscosity are the properties that affect drag force the most. Neither density nor viscosity change noticeably in our experiment. For the density of the water to change considerably the depth of the swimmer would have to differ immensely. Viscosity as well is not greatly changed in our experiment. We can ignore changes in these properties because we are almost exactly repeating our conditions for each different body position.

Methods and Materials:

In this lab a section of the Dickinson pool was set up so that we could video tape underwater pushoffs. On one side of the pool a camera was connected to a periscope which enabled us to take underwater footage without the need for an underwater camera.

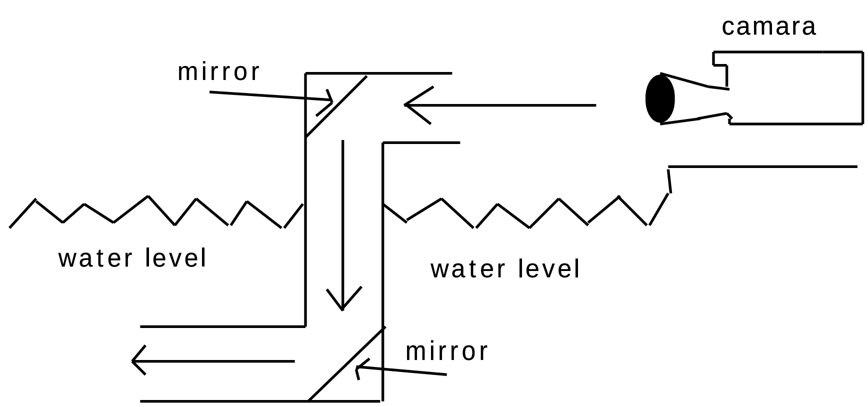


Figure 2: a diagram of a periscope that we used to record underwater motion. The mirrors reflect light and make it possible for us to see underwater without getting wet.

On the side of the pool opposite of the camera, cones are placed underwater and at the same distance from the camera as the swimmer. The two cones are placed one meter apart and will be used as a scale in the video analysis of the motion. With the setup now complete we can begin to take video footage of the swimmer pushing off and gliding in different positions.

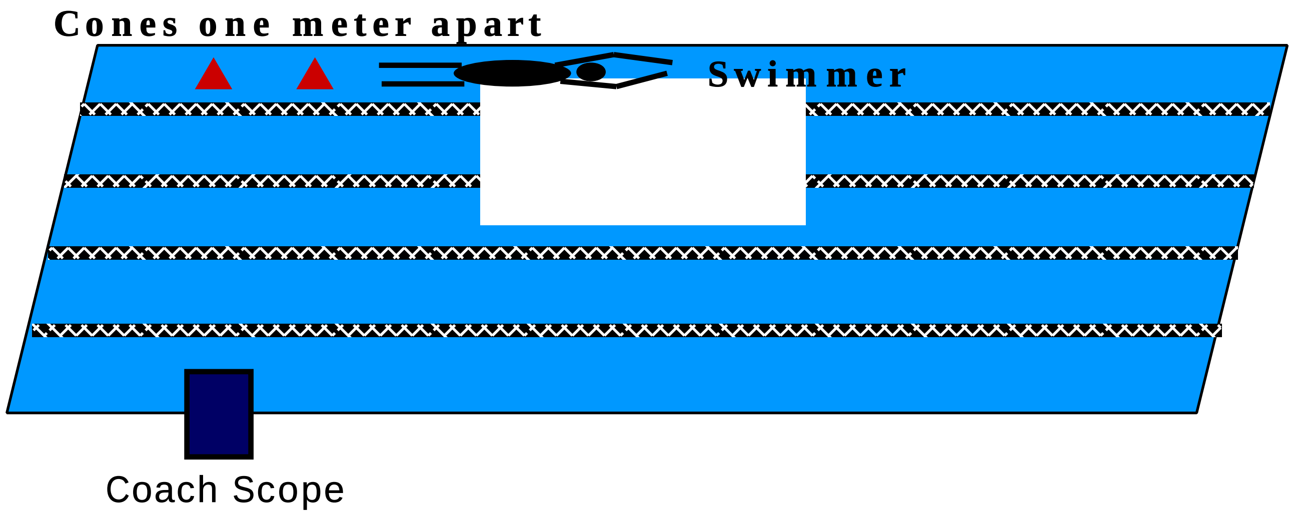


Figure 3: picture of our experiment setup, showing scope/video camera, cones used for our scale, and the swimmer

In this footage we analyzed a swimmer gliding with his arms forward and a swimmer with his arms to his side. Using the video footage of this motion we will investigate which of the two gliding positions offers the least resistance, and therefore less affected by the force of water friction. After the video footage is taken we digitize the motions and save them as computer video files. Using a remarkable tool called VideoPoint™, which can do frame by frame analysis of the gliding motion. This will provide the linear displacement of the swimmer's position along the x-axis (horizontal plane). From this data we can examine our position displacement and find the Force of water friction and the resulting deceleration of the swimmer due to friction.

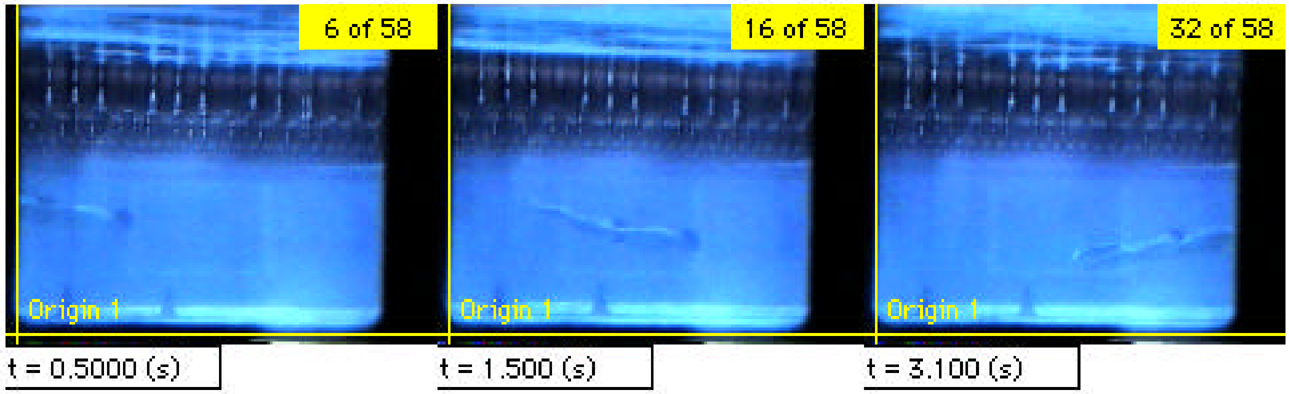


Figure 4: swimming with arms to the side.

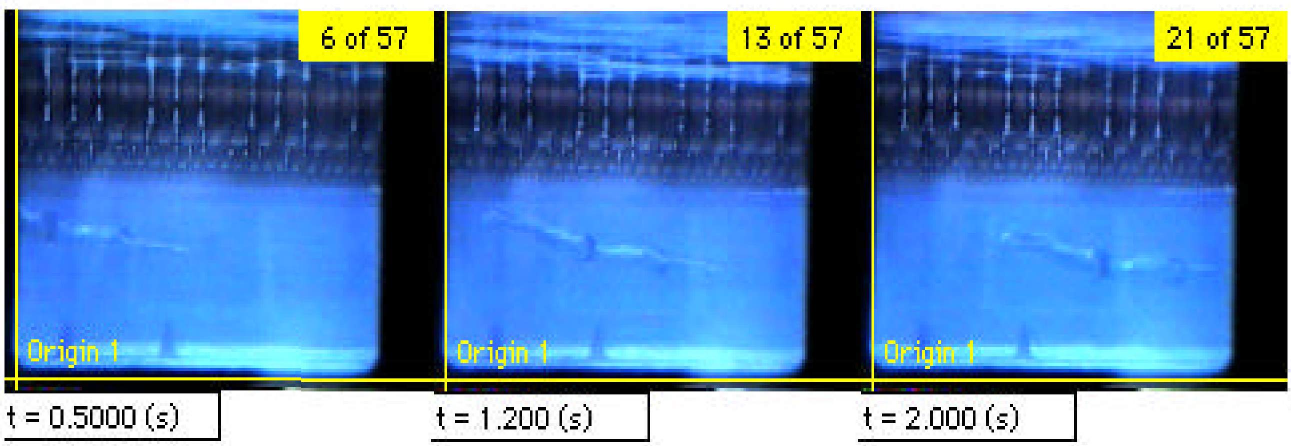


Figure 5: swimming with arms forward.

Data Collection:

We used a special device called a coach scope to take video images under water. It is simply an L shaped device with two mirrors. The camera points at the first mirror above water witch tilts the light down the mirror under the water witch then records everything under the water. (Pictures above)

For a scale we placed two orange cones exactly one meter apart directly underneath the path of the swimmer. This can be used by video point to produce real distances instead of using pixels. We then recorded the two different pushoffs several different times.

We downloaded our video into the computer and used the Video Point program to analyze the images. We clicked the mouse on the swimmers hand in each frame for both movies. We then cut the data table created by video point and pasted it into the Excel. Since we are only examining the horizontal motion of the swimmer, we only used the X-coordinates. We worked under the assumption that our swimmer was undergoing form drag, and therefore we used the equation

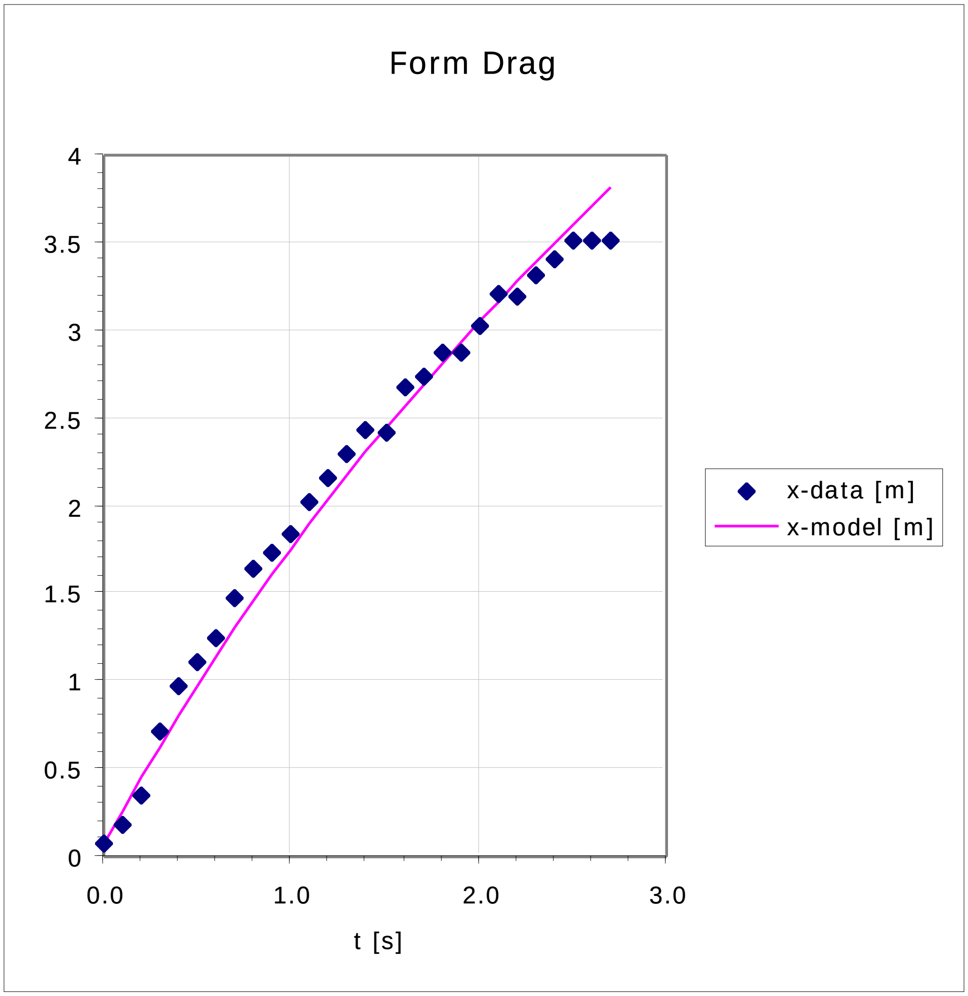
$$\vec{F}_{DX} = -\tfrac{1}{2} C \rho_w A_{swimmer} V^2 \hat{x}$$

to figure out the drag coefficient of the swimmer. From this we can determine which body position is the most streamlined and offers the least resistance to water.

Arms forward data

See Appendix A data.

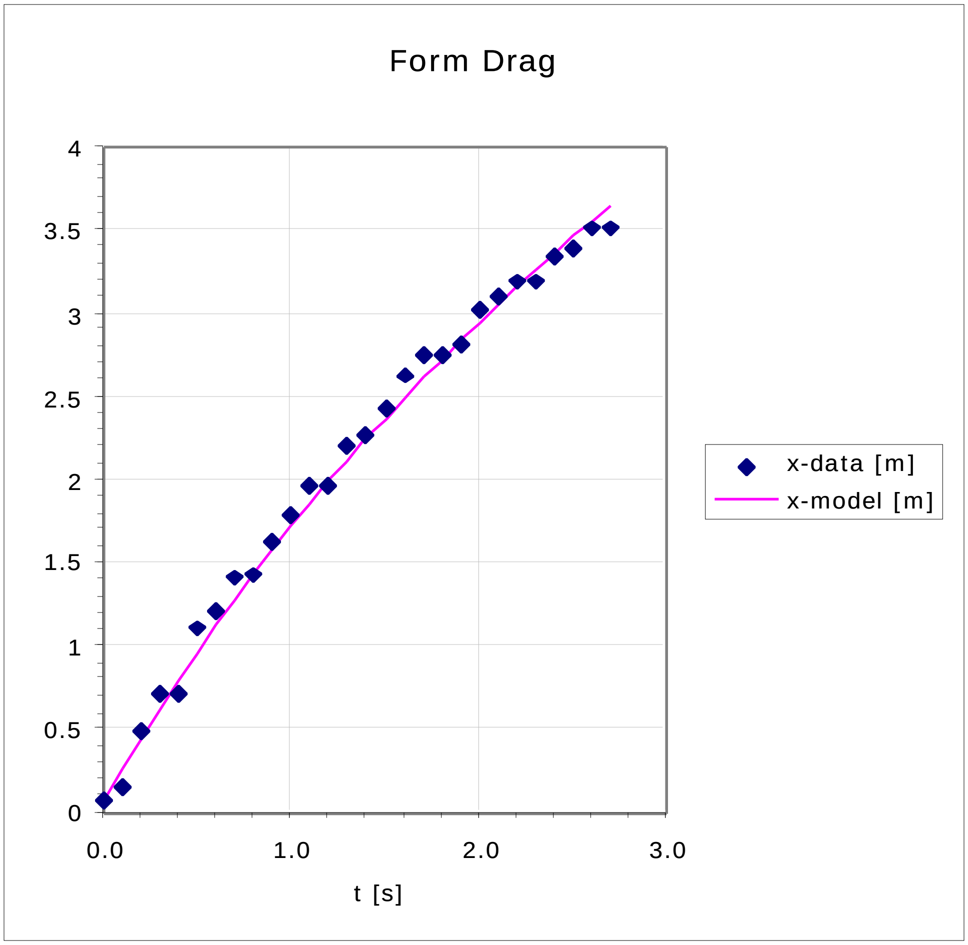
	A	0.07	[m^2]		m	79.5	[kg]
	ρ (H2O)	1000.00	[kg/m^3]				
	C	0.39			Δt	0.10	[s]
	x_o	0.07	[m]		a_g	0	[m/s^2]
	v_{ox}	2.00	[m/s]				



Arms to the side data

See Appendix B for data.

	A	0.07	[m^2]		m	79.5	[kg]
	ρ (H2O)	1000.00	[kg/m^3]				
	C	0.45			Δt	0.10	[s]
	x_o	0.07	[m]		a_g	0	[m/s^2]
	v_{ox}	2.00	[m/s]				



Based on our data we can conclude that the swimmer with his arms forward is affected less by frictional forces, and therefore will maintain a larger velocity for a longer period of time.

Results:

In this lab we determined which of three body forms offer the least resistance to water, and therefore least affected by the force of water drag. In this experiment we tested our data assuming that it either experienced form or viscous drag. Testing both we found that both viscous and form drag methods worked. We used form drag to analyze our data because it provided the best fit for our data. Unfortunately, our third body form, in which the swimmer's arms were outstretched did not work due to errors in the digitized movie. Although, appropriate data was not obtained it is clear to us that this form offered the greatest resistance and was affected the most by water drag. Both of these methods produced accurate results, however using form drag made more logical sense due to the fact that the opposing force of the water changes with the velocity of the swimmer. We calculated the coefficient of friction to be much greater pushing off the wall with arms to the side. One reason for this is because more surface area of the swimmer is perpendicular to the intended direction of travel. With the two body forms that gave us accurate data, we discovered that the position, in which the swimmer's arms reached forward, offered the least resistance. Its drag coefficient was measured to be 0.39. For the body position where the swimmer's arms were to his side, the drag coefficient was 0.45.

Conclusions:

This experiment shows that water friction acts like air friction but slows down the objects much faster. The drag caused by the swimmer having their arms at their side was greater then a tight streamlined position above the head. We also found that pushing off with arms forward was affected by the least drag force opposing the direction of motion. This means that the swimmer remains at a faster velocity for a longer time, making that body position more effective and faster in swim meets.

The shaking of the camera caused by waves may have caused some uncertainty in our data, and the poor quality of the video may have contributed to blurry reference points to be blurry. It is also impossible for the swimmer to glide in a perfect horizontal path. Since the swimmer can change shapes, the swimmer may bend or move slightly and skew the results.

Our experiment was successful in determining the most fluid body position, however, we experienced a few minor problems. One major obstacle that we confronted came when we had to decide whether our swimmer experienced form drag or viscous drag. Since both forms offered acceptable solutions, it was not a major concern. Overall, our project was a success. We were able to prove that a swimmer with his arms forward offered the least resistance to water drag.

Appendix A:

	Form Drag					
Fr#	t [s]	x-data [m]	Fx [N]	ax-model [m/s^2]	vx-model [m/s]	x-model [m]
1	0.0	0.07	-54.6	-0.687	2.000	0.070
2	0.1	0.18	-50.9	-0.640	1.931	0.263
3	0.2	0.35	-47.6	-0.599	1.867	0.450
4	0.3	0.72	-44.6	-0.561	1.807	0.631
5	0.4	0.98	-41.9	-0.527	1.751	0.806
6	0.5	1.11	-39.4	-0.495	1.699	0.976
7	0.6	1.25	-37.1	-0.467	1.649	1.141
8	0.7	1.47	-35.0	-0.441	1.602	1.301
9	0.8	1.65	-33.1	-0.417	1.558	1.457
10	0.9	1.74	-31.4	-0.395	1.517	1.608
11	1.0	1.84	-29.8	-0.375	1.477	1.756
12	1.1	2.02	-28.3	-0.356	1.440	1.900
13	1.2	2.16	-26.9	-0.338	1.404	2.040
14	1.3	2.3	-25.6	-0.322	1.370	2.177
15	1.4	2.43	-24.4	-0.307	1.338	2.311
16	1.5	2.42	-23.3	-0.293	1.307	2.442
17	1.6	2.67	-22.3	-0.280	1.278	2.570
18	1.7	2.74	-21.3	-0.268	1.250	2.695
19	1.8	2.87	-20.4	-0.257	1.223	2.817
20	1.9	2.87	-19.6	-0.246	1.197	2.937
21	2.0	3.03	-18.8	-0.236	1.173	3.054
22	2.1	3.21	-18.0	-0.227	1.149	3.169
23	2.2	3.19	-17.3	-0.218	1.126	3.282
24	2.3	3.31	-16.7	-0.210	1.105	3.392
25	2.4	3.4	-16.0	-0.202	1.084	3.500
26	2.5	3.51	-15.4	-0.194	1.064	3.607
27	2.6	3.51	-14.9	-0.187	1.044	3.711
28	2.7	3.51	-14.4	-0.181	1.025	3.814

Appendix B:

	Form Drag					
Fr#	t [s]	x-data [m]	Fx [N]	ax-model [m/s^2]	vx-model [m/s]	x-model [m]
1	0.0	0.07	-63.0	-0.792	2.000	0.070
2	0.1	0.15	-58.1	-0.731	1.921	0.262
3	0.2	0.48	-53.8	-0.676	1.848	0.447
4	0.3	0.71	-49.9	-0.628	1.780	0.625
5	0.4	0.71	-46.4	-0.584	1.717	0.797
6	0.5	1.11	-43.3	-0.545	1.659	0.962
7	0.6	1.21	-40.5	-0.510	1.604	1.123
8	0.7	1.42	-38.0	-0.478	1.553	1.278
9	0.8	1.43	-35.7	-0.449	1.506	1.429
10	0.9	1.63	-33.6	-0.423	1.461	1.575
11	1.0	1.80	-31.7	-0.399	1.418	1.717
12	1.1	1.96	-29.9	-0.376	1.379	1.855
13	1.2	1.96	-28.3	-0.356	1.341	1.989
14	1.3	2.2	-26.8	-0.338	1.305	2.119
15	1.4	2.26	-25.5	-0.320	1.271	2.246
16	1.5	2.43	-24.2	-0.304	1.239	2.370
17	1.6	2.63	-23.0	-0.290	1.209	2.491
18	1.7	2.75	-21.9	-0.276	1.180	2.609
19	1.8	2.75	-20.9	-0.263	1.152	2.724
20	1.9	2.82	-20.0	-0.251	1.126	2.837
21	2.0	3.03	-19.1	-0.240	1.101	2.947
22	2.1	3.1	-18.3	-0.230	1.077	3.055
23	2.2	3.2	-17.5	-0.220	1.054	3.160
24	2.3	3.2	-16.8	-0.211	1.032	3.263
25	2.4	3.35	-16.1	-0.202	1.011	3.365
26	2.5	3.39	-15.5	-0.194	0.991	3.464
27	2.6	3.52	-14.9	-0.187	0.971	3.561
28	2.7	3.51	-14.3	-0.180	0.953	3.656