Balloons and Gas Laws
Data Analysis

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Volume of Balloon

- We measured two circumferences, call them C_1 and C_2.
- Radii calculated by $R_1 = C_1/2\pi$ inches = $C_1 * 2.54/2\pi$ cm.
- Volume can be calculated as $4\pi R_1^2 R_2/3 = 4\pi C_1^2 C_2 2.54^3 / (3*(2\pi)^3)$ $cm^3 = C_1^2 C_2 2.54^3 / (6*\pi^2)$ $cm^3 = .276726 * C_1^2 C_2$ cm^3

12 inch balloons – Analysis

- Lift is M_{air}-M_{helium}-$M_{balloon}$
  - M_{air} =28.96*P_{amb}*V/R T = 28.96*.977*V/(.08205 296)
  - M_{helium} =4.00*P_{int}*V/R T = 4.00*1.000*V/(.08205 296)
- Can write above formula as: Lift=24.29*V/(. 08205 296) - $M_{balloon}$ = 1.0003*V - $M_{balloon}$

12 inch balloons – Data

	Balloons	10/20/2004							
	Not Happy Birthday								
	Mass	Circum-1	Circum-2	Volume	Lift	Rise	Rise	Error	Error
	with string				Actual	Time	Time		
	grams	inches	inches	liters	grams	Student	Dave	Student	Dave
Orange	3.83	24	26	4.144249	0.14	15.22	14.85	0.46	0.74
Green	3.77	26	29.5	5.51847	2.15	4.60	4.46	0.31	0.165
Red	4.01	30.5	33.25	8.55936	4	4.04		0.23	0
Blue	4.21	31.5	34	9.335767	5.28	3.78	3.75	0.33	0.245
Yellow	3.85	37	37	14.017	7.01	3.42	3.44	0.18	0.275
	Times - Student				Times - Dave				
Orange	15.58	14.67	15.42		15.06	14	15.48		
Green	4.61	4.97	4.47	4.36	4.31	4.64	4.54	4.33	
Red	4.29	4.09	3.93	3.83					
Blue	3.4	3.9	4.06	3.77	3.9	3.54	4.03	3.54	
Yellow	3.64	3.33	3.29		3.12	3.67	3.54		

12 inch balloons – Analysis

- Terminal velocity of a balloon satisfies: $v_0^2=4*LIFT*g/\rho A$
  - LIFT is lift of balloon
  - g is gravitational constant 9.8 m/sec^2
  - ρ is density of air in kg/m^3
  - A is cross-sectional area of balloon
    - πR_1^2

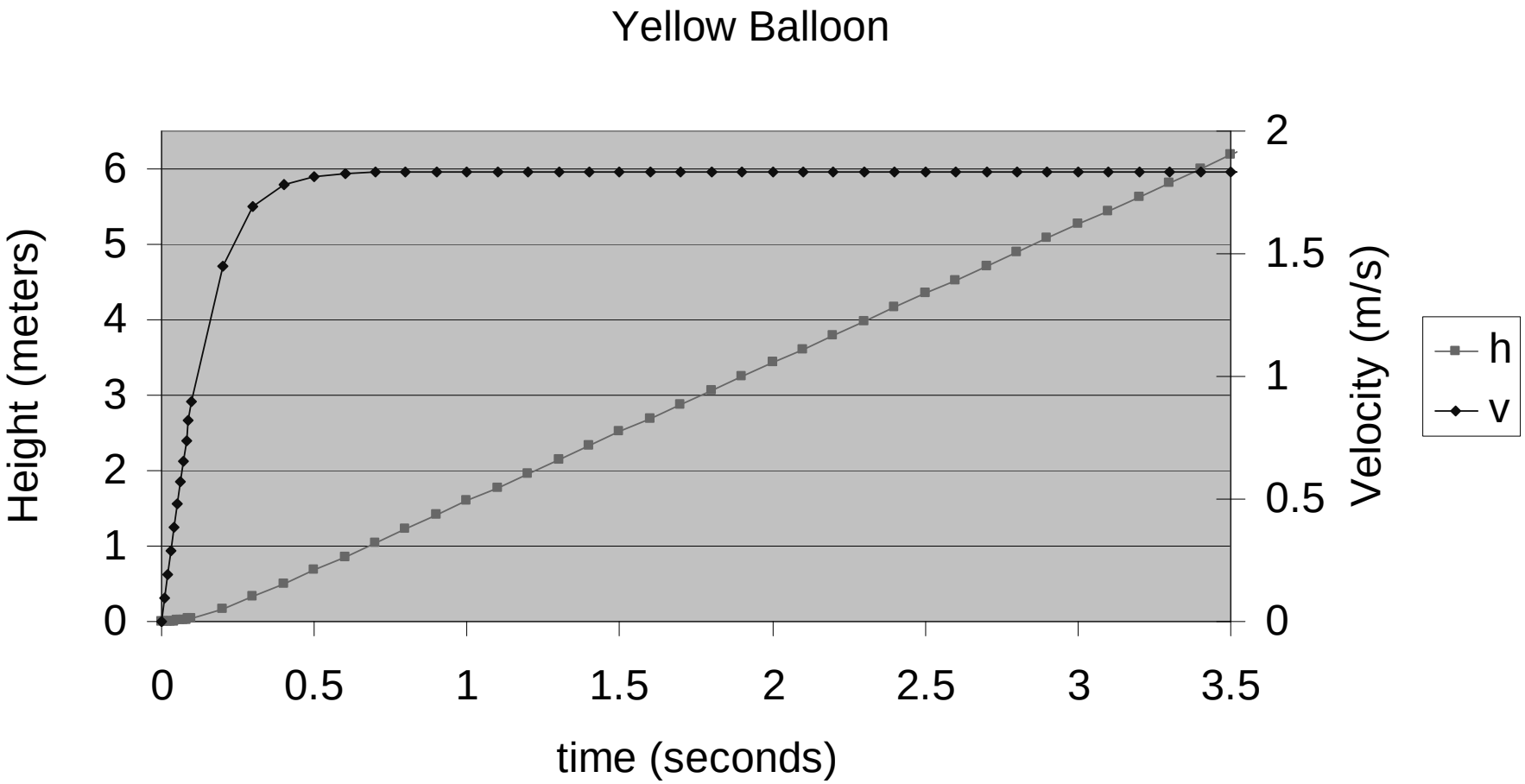
12 inch balloons – Analysis

- Can solve for velocity, height of balloon as a function of time:
  - $V = v_0 \tanh(v_0 C t)$
    - $C = \rho A/4$ LIFT
    - tanh is hyperbolic tangent
  - Height = $\ln[\cosh(v_0 C t)] / C$
    - ln is natural logarithm
    - cosh is hyperbolic cosine
  - Time to rise 5.87 meters is: $\operatorname{arccosh}[\exp(5.87*C)]/ v_0 C$

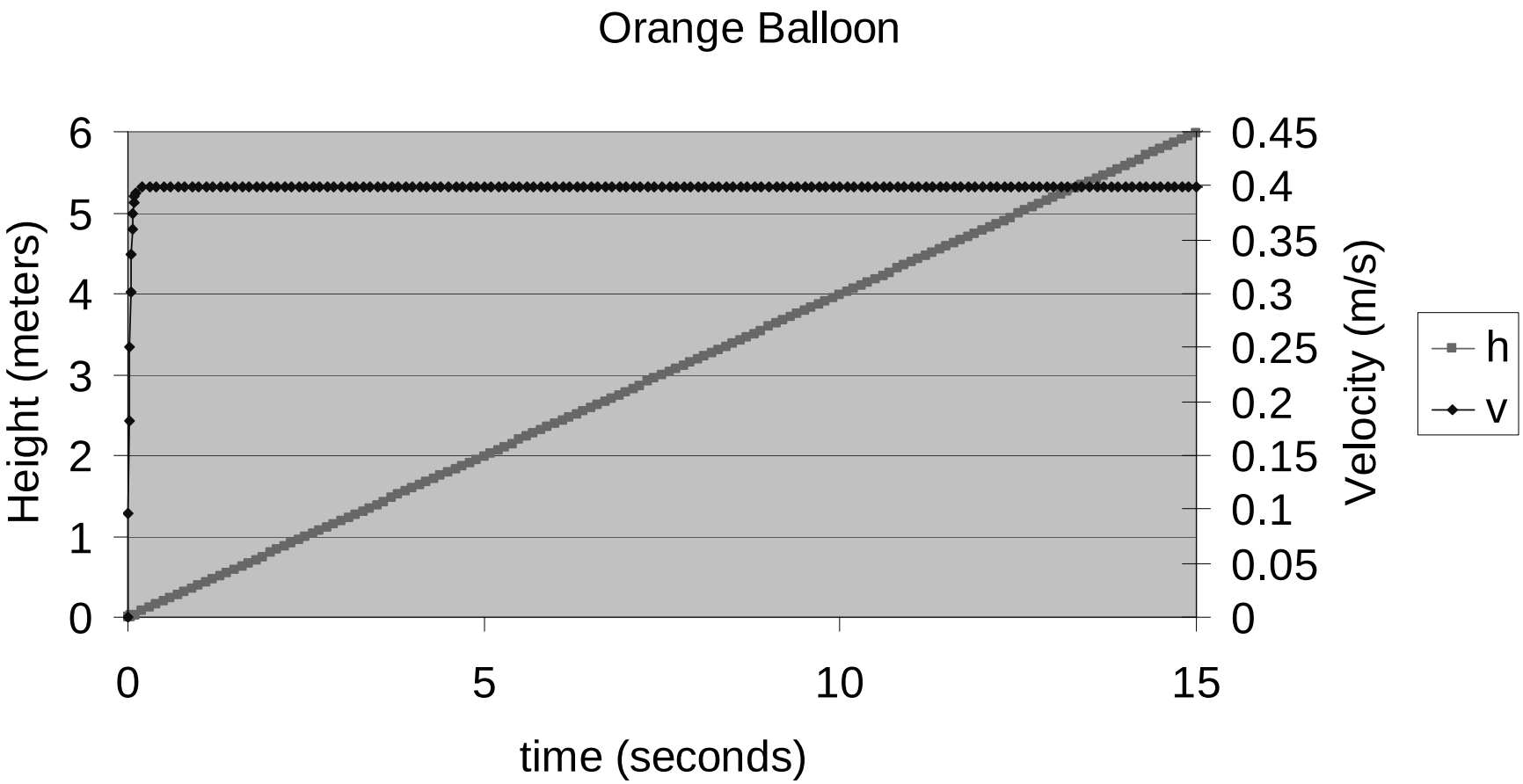
12 inch balloons – Analysis

						Terminal
	Volume	Lift	Lift	Rise Rate	Rise Rate	Velocity
		Actual	Theoretic	Student	David	Theoretical
	liters	grams	grams	m/s	m/s	m/s
Orange	4.14	0.14	0.217	0.385	0.395	0.399352
Green	5.52	2.15	1.619	1.275	1.317	1.444606
Red	8.56	4.00	4.348	1.454		1.679708
Blue	9.34	5.28	4.907	1.551	1.564	1.868572
Yellow	14.02	7.01	9.838	1.716	1.704	1.832993
		Area				
			Rise	Rise	Rise	
			Time	Time	Time	
	C	m^2	Student	David	Theoretical	
Orange	61.45	0.03	15.22	14.85	14.73	
Green	4.696	0.035	4.60	4.46	4.14	
Red	3.473	0.048	4.04		3.59	
Blue	2.807	0.051	3.78	3.75	3.25	
Yellow	2.917	0.07	3.42	3.44	3.31	

12 inch balloons – Analysis



12 inch balloons – Analysis



9 inch balloons – Data

	Balloons	10/20/2004							
	Happy Birthday								
	Mass	Circum-1	Circum-2	Volume	Lift	Rise Time	Rise Time	Error	Error
	with string				Actual	Student	Dave	Student	Dave
	grams	inches	inches	liters	grams	seconds	seconds	seconds	seconds
Purple	2.85	22.75	24	3.437352	0.78	6.40	6.27	0.20	0.185
Yellow	2.63	23	25	3.659701	1.04	5.67	5.67	0.51	0.28
Blue	3.06	25	25.75	4.453559	1.41	5.24	5.15	0.48	0.275
Red	2.5	25.5	28.5	5.128321	2.79	3.97	3.89	0.30	0.725
Pink	3.65	28	31.5	6.834025	3.1	4.14	4.07	0.17	0.055
Orange	2.75	27.5	31.9	6.675842	4.32	3.39	3.58	0.06	0.045
	Times - Student				Times - Dave				
Purple	6.45	6.18	6.57		6.04	6.41	6.36		
Yellow	6.18	5.16	5.68		5.85	5.3	5.86		
Blue	5.65	5.36	4.69	5.27	4.83	5.1	5.28	5.38	
Red	3.77	3.78	4.36		3.09	4.04	4.54		
Pink	4.16	3.97	4.3		4.12	4.01	4.07		
Orange	3.35	3.35	3.48		3.57	3.54	3.63		

9 inch balloons – Analysis

						Terminal
	Volume	Lift	Lift	Rise rate	Rise rate	Velocity
		Actual	Theoretical	Student	David	Theoretical
	liters	grams	grams	m/s	m/s	m/s
Purple	3.437	0.78	0.585	0.917	0.936	0.994419005
Yellow	3.660	1.04	1.027	1.034	1.035	1.135775115
Blue	4.454	1.41	1.390	1.119	1.140	1.216670738
Red	5.128	2.79	2.624	1.478	1.508	1.677897537
Pink	6.834	3.10	3.179	1.416	1.443	1.61074329
Orange	6.676	4.32	3.920	1.729	1.639	1.936032729
	C	Area	Rise Time	Rise Time	Rise Time	
			Student	David	Theoretical	
	1/m	m^2	seconds	seconds	seconds	
Purple	10.4668	0.0266	6.40	6.27	5.93	
Yellow	8.0236	0.0272	5.67	5.67	5.21	
Blue	6.9921	0.0321	5.24	5.15	4.88	
Red	3.6764	0.0334	3.97	3.89	3.59	
Pink	3.9893	0.0403	4.14	4.07	3.73	
Orange	2.7614	0.0388	3.39	3.58	3.15	

9 inch balloons – Analysis

Pressure	Height	Width		Pressure	Volume	PV
	inches	inches		atm	cm^3	
742.4	4.5	4.5		0.976842	25.21666	24.63269
9	6	5.5		0.676053	50.22577	33.95526
15	7	6		0.475526	69.73495	33.1608
20	8.5	7		0.308421	115.2564	35.54749
23	9	8		0.208158	159.3942	33.17916
100	10.5	8		0.131579	185.9599	24.4684
50	10	8.5		0.065789	199.9345	13.15359
20	12	9.5		0.026316	299.6943	7.886691

- Note that PV is not constant
- However, down to about 100 Torr, PV is sort-of constant
- What are possible explanations?