

Fall 2002

FL

8.01X

Data and Graphs

Expt FLOW DATA

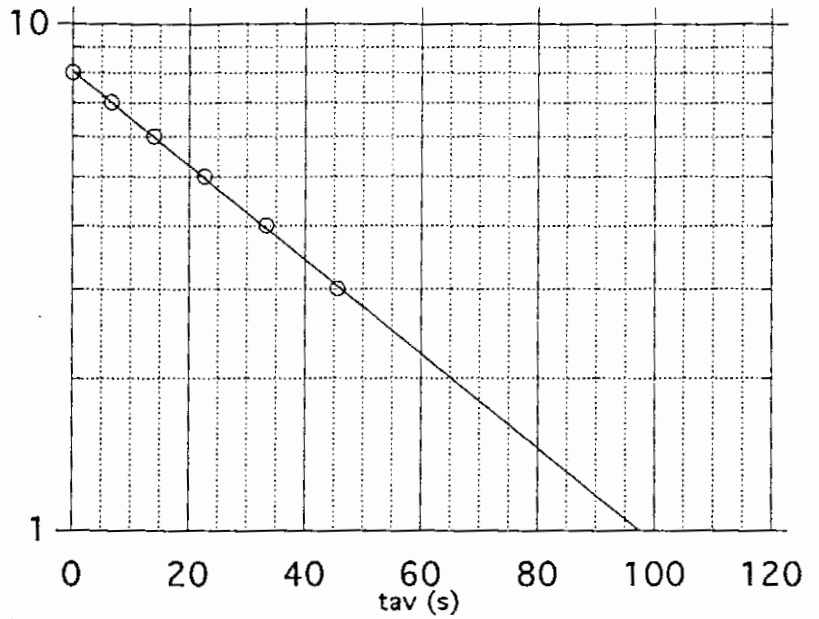
$y = 8.08 * e^{(-0.0214x)} R = 1$

for  $L = 131 \text{ mm}$

$$\text{slope} = \frac{\ln(40) - \ln(81)}{(32.5 - 0) \text{ s}}$$

$$= -0.0217 \frac{1}{\text{s}}$$

	Head (cm)	t1 (s)	t2 (s)	t3 (s)	tav (s)	SD(s)
0	8	0.1	0.1	0.1	0.1	0.1
1	7	7	6	7	6.7	0.5
2	6	14	14	14	14.0	0.0
3	5	22	23	23	22.7	0.5
4	4	34	33	33	33.3	0.5
5	3	46	45	46	45.7	0.5
6	1					
7	0					



Head

$y = 8.08 * e^{(-0.0214x)} R = 1$

time constant

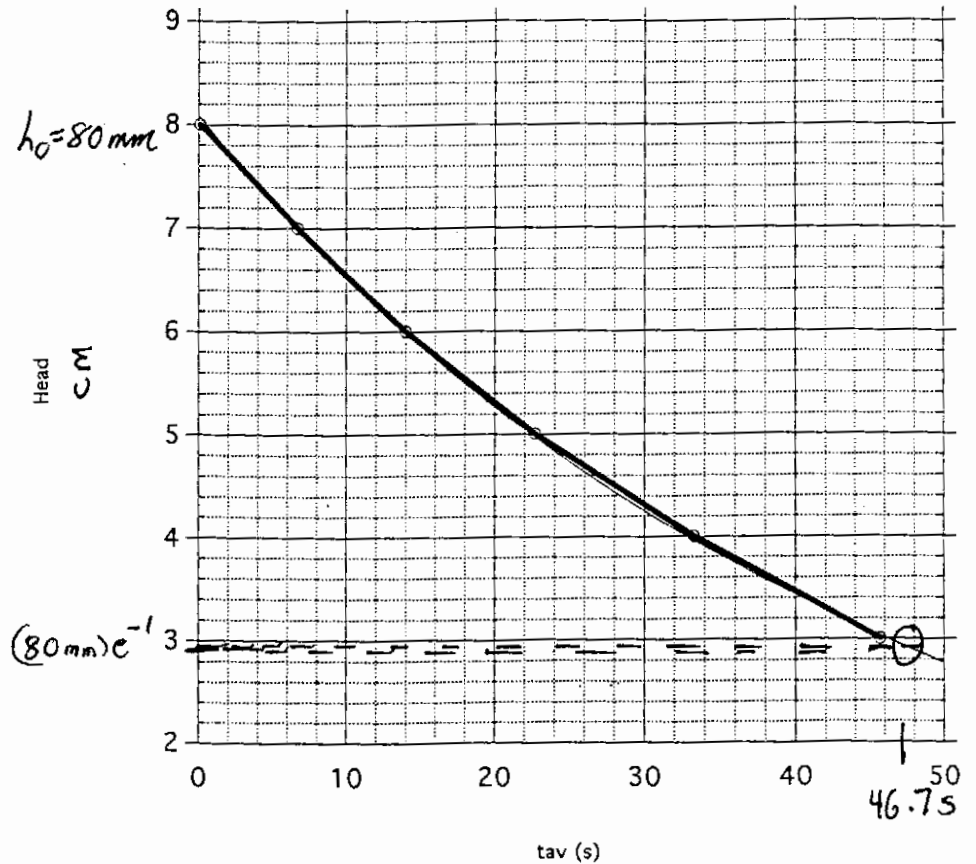
$$\tau = \frac{1}{\alpha} = \frac{1}{0.0214} \text{ s}$$

$$= 46.7 \text{ s}$$

$$h(t = \tau) = h_0 e^{-1} = 46.7 \text{ s}$$

$h_0 = 80 \text{ mm}$

FL 8-31-98 131mm



# Data Chart + Graphs

for

$$L = 261 \text{ mm}$$

$$\text{Slope} = \frac{\ln(50) - \ln(80.4)}{(57.5 - 0)5}$$

$$= -0.00826 \frac{1}{s}$$

Head (cm)

$h_0 e^{-\lambda z}$

	Head (cm)	t1 (s)	t2 (s)	t3 (s)	tav (s)	SD(s)
0	8	0	0	0	0.0	0.0
1	7	15	17	18	16.7	1.2
2	6	30	35	41	35.3	4.5
3	5	47	58	68	57.7	8.6
4	4	70	83	99	84.0	11.9
5	3	97	120	140	119.0	17.6
6	2	138	166	196	166.7	23.7
7	1					
8	0					

$$\lambda = \frac{1}{\alpha} = \frac{1}{0.00832}$$

$$= 120 \text{ s}$$

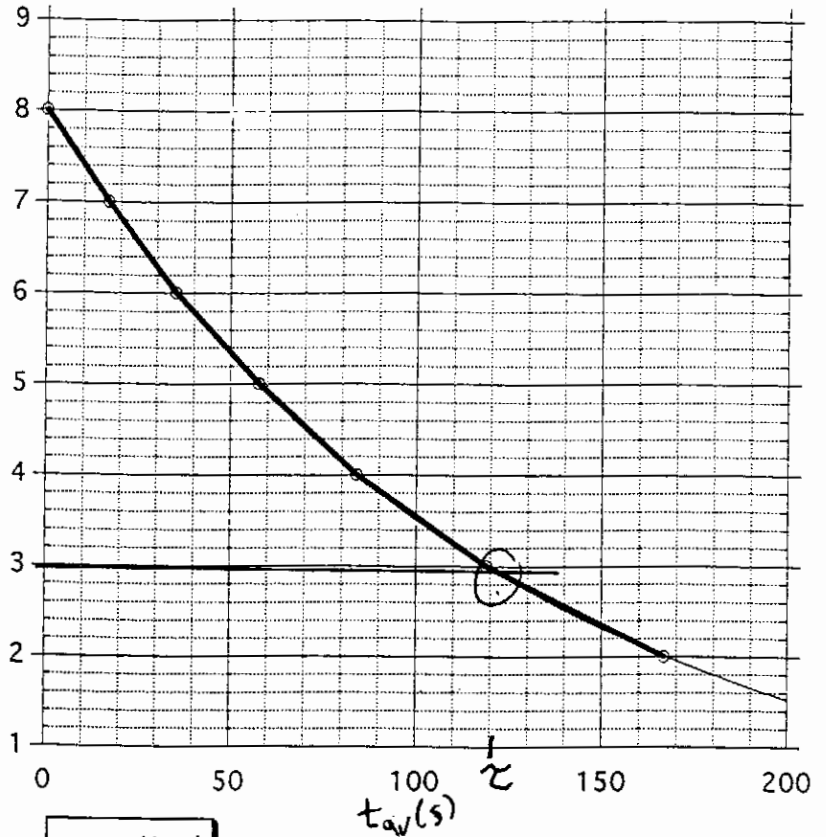
$$h(\lambda) = 8.04 e^{-1} = 2.96 \text{ cm}$$

Head (cm)

Head

$$y = 8.04 * e^{(-0.00832x)} R=1$$

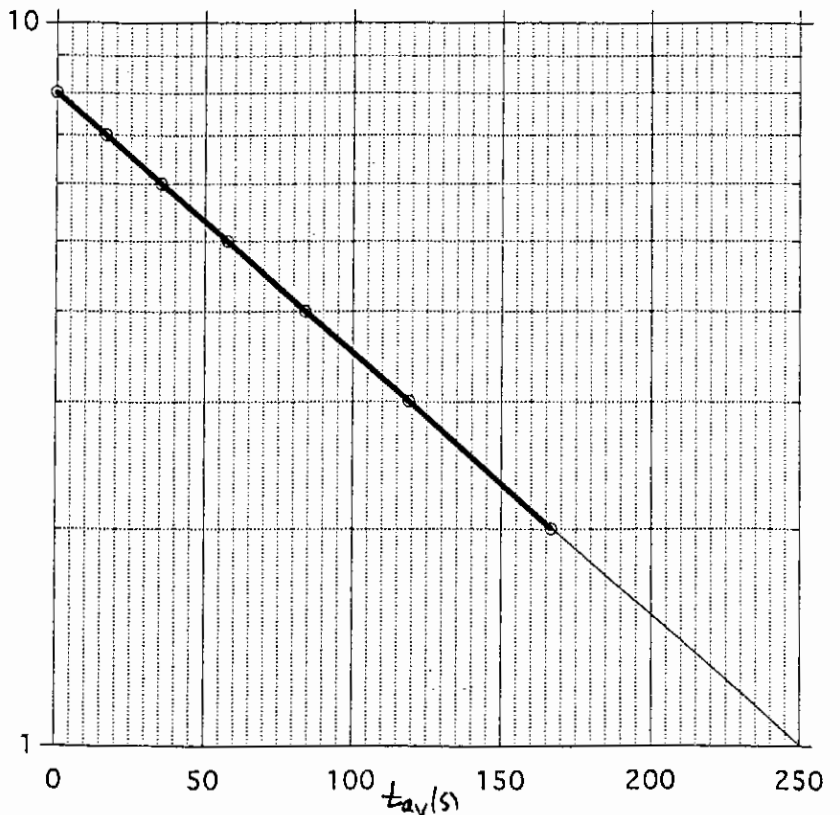
(261)mm



Head

$$y = 8.04 * e^{(-0.00832x)} R=1$$

(261)mm



Data and Graphs  
for  $L = 390 \text{ mm}$

$$\text{slope} = \frac{\ln(70) - \ln(81.0)}{(21 - 0) \text{ s}}$$

$$= -6.95 \times 10^{-3} \frac{1}{\text{s}}$$

my computer plotted  
e slope

$$= -7.24 \times 10^{-3} \frac{1}{\text{s}}$$

	Head cm	t1 (s)	t2 (s)	t3 (s)	tav (s)	SD(s)
0	8	0	0.1	0.1	0.1	0.1
1	7	17	22	23	20.7	2.6
2	6	38	45	48	43.7	4.2
3	5	61	69	75	68.3	5.7
4	4	90	100	108	99.3	7.4
5	3	123	137	147	135.7	9.8
6	1					
7	0					

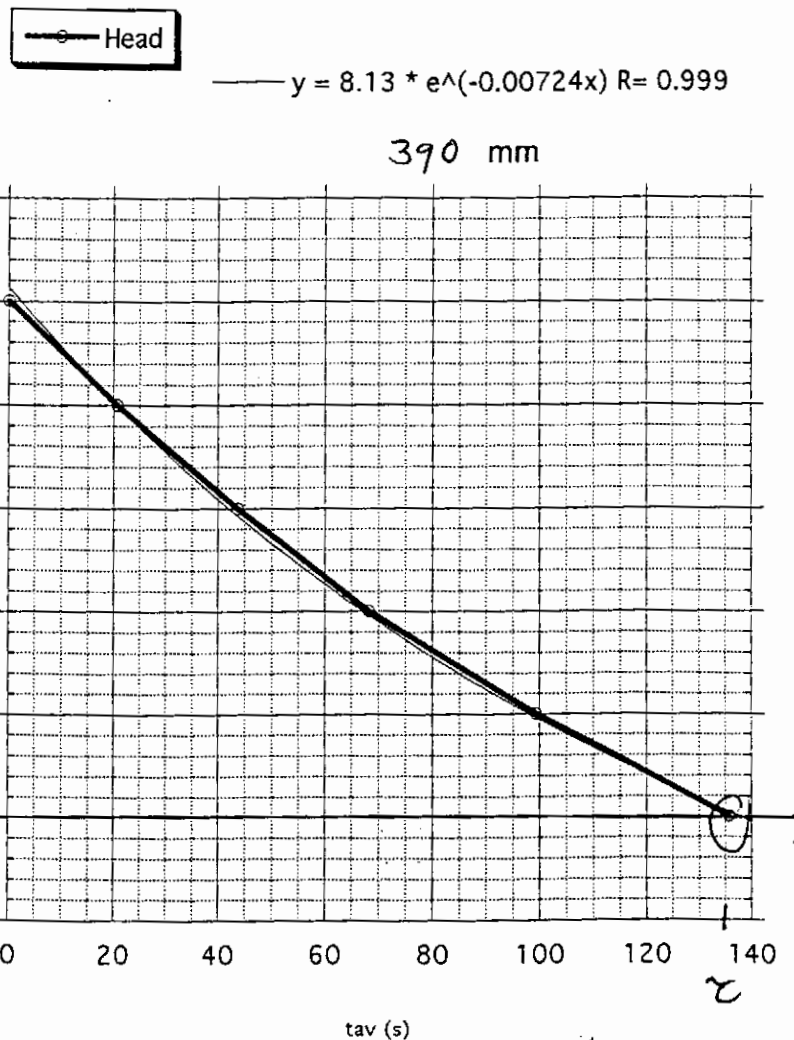
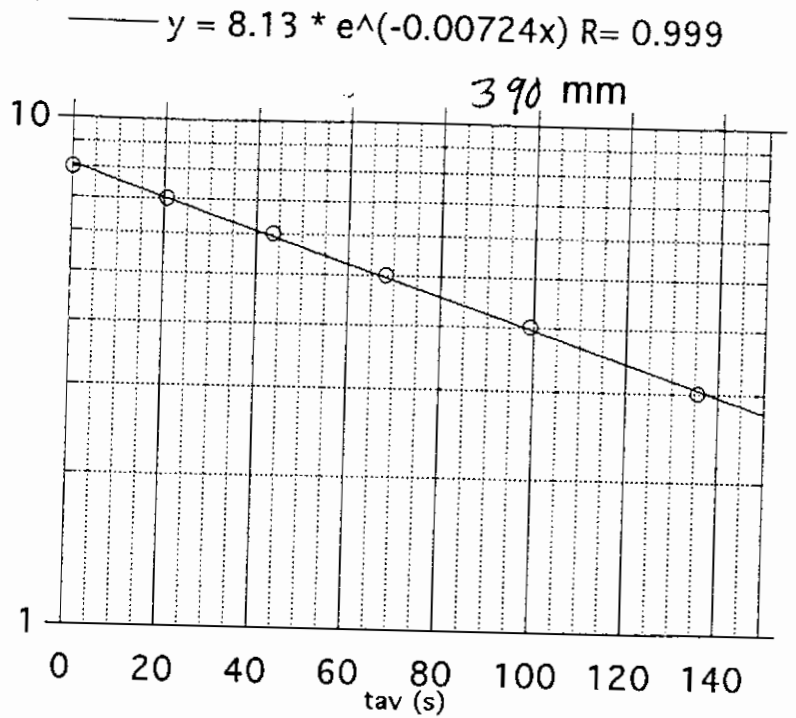
time constant

$$\tau = 138 \text{ s}$$

$$h(\tau) = h_0 e^{-1} = (8.13) e^{-1}$$

$$= 30 \text{ mm}$$

$$h_0 e^{-1}$$



# Viscosity Calculations:

$$R = \frac{2.8}{2} \times 10^{-3} \text{ m}, \quad \rho = 1.0 \times 10^3 \frac{\text{kg}}{\text{m}^3}$$

$$A = \pi \left(\frac{d}{2}\right)^2 \text{ where } d = 63.5 \times 10^{-3} \text{ m}$$

$$A = 3.17 \times 10^{-3} \text{ m}^2$$

$$\eta = \frac{-\pi \rho g R^4}{A \delta L (\text{slope})}, \quad \text{slope} = -\alpha$$

$$\eta_1 = \frac{\pi \rho g R^4}{A \delta L, \alpha_1} = \frac{(\pi)(1.0 \times 10^3 \frac{\text{kg}}{\text{m}^3})(9.8 \frac{\text{m}}{\text{s}^2})(1.4 \times 10^{-3} \text{ m})^4}{(3.17 \times 10^{-3} \text{ m}^2)(8)(0.131 \text{ m})(\frac{0.0214}{5})}$$

$$= 1.7 \times 10^{-3} \text{ Pa-s}$$

$$\eta_2 = \frac{(\pi)(1.0 \times 10^3 \frac{\text{kg}}{\text{m}^3})(9.8 \frac{\text{m}}{\text{s}^2})(1.4 \times 10^{-3} \text{ m})^4}{(3.17 \times 10^{-3} \text{ m}^2)(8)(0.261 \text{ m})(\frac{0.00832}{5})} = 2.1 \times 10^{-3} \text{ Pa-s}$$

$$\eta_3 = \frac{(\pi)(1.0 \times 10^3 \frac{\text{kg}}{\text{m}^3})(9.8 \frac{\text{m}}{\text{s}^2})(1.4 \times 10^{-3} \text{ m})^4}{(3.17 \times 10^{-3} \text{ m}^2)(8)(0.390 \text{ m})(\frac{0.00724}{5})} = 1.7 \times 10^{-3} \text{ Pa-s}$$

Since the viscosity

$$\eta = \frac{-\pi \rho g R^4 L}{A \delta L \text{ (slope)}}$$

$$\frac{1}{\text{slope}} = \frac{1}{(-\alpha)} = -\tau$$

$\tau$  = Time constant

$$\eta = \frac{\pi \rho g R^4 \tau}{A \delta L}$$

$$\tau = \frac{A \delta \eta L}{\pi \rho g R^4}$$

$$\text{slope} = \frac{A \delta \eta_{ave}}{\pi \rho g R^4}$$

$$\eta_{ave} = \frac{\pi \rho g R^4 (\text{slope})}{A \delta}$$

$$= \frac{(0.353 \times 10^{-3} \frac{s}{m}) (\pi) (1.0 \times 10^3 \frac{kg}{m^3}) (9.8 \frac{m}{s^2}) (1.4 \times 10^{-3} m)^4}{(3.17 \times 10^{-3} m^2) (8)}$$

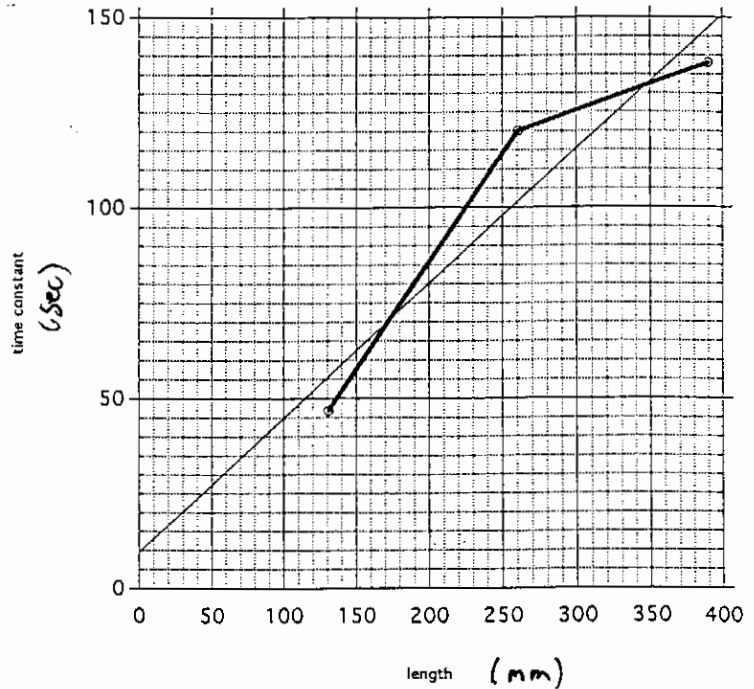
$$\eta_{ave} = 1.6 \times 10^{-3} \text{ Pa}\cdot\text{s}$$

	length	time constant
0	131	46.7
1	261	120
2	390	138

—○— time constant

$$y = 9.61 + 0.353x$$

$$y = 9.61 + 0.353x \quad R = 0.945$$



notice that when  $L=0$   
 $\Rightarrow \tau=0$  but this is unphysical since  $L=0$  is the case of a hole and it takes a finite amount of time to empty the bottle.

Laminar flow is not established for short  $L$   
 Turbulence dominates!

Thus  $\eta = \frac{-\pi \rho g R^4}{48 L (\text{slope})}$ , I measured the radius of

the pipe to be  $R = 1.5 \times 10^{-3} \text{ m}$ . This is not very accurate and is the greatest source of error for my value of  $\eta$  because

$\frac{\Delta \eta}{\eta} \approx 4 \frac{\Delta R}{R}$  since  $R$  is raised to the fourth power. if  $\Delta R \approx 0.2 \times 10^{-3} \text{ m}$ ,  $\frac{\Delta R}{R} \approx \frac{0.2 \times 10^{-3} \text{ m}}{1.5 \times 10^{-3} \text{ m}} \approx 0.13$  and  $\frac{\Delta \eta}{\eta} \approx 4 \times 0.13 = 0.53$ . 50% error.

The measured diameter for the water bottle  $d = 63.5 \times 10^{-3} \text{ m}$

So  $A \approx \pi \left(\frac{d}{2}\right)^2$ . Thus if  $\Delta d \approx 1.0 \times 10^{-3} \text{ m}$ .

$\frac{\Delta A}{A} \approx 2 \frac{\Delta d}{d}$  and since we need  $A^2$

$\frac{\Delta A}{A} \approx 2 \frac{\Delta d}{d} \approx (2) \left(\frac{1.0 \times 10^{-3} \text{ m}}{63.5 \times 10^{-3} \text{ m}}\right) \approx 0.031$  or 3.1%  $A$

much smaller error

$\frac{\Delta L}{L} \approx \frac{0.5 \text{ mm}}{129 \text{ mm}} \approx 3.9 \times 10^{-3}$  or 0.39% (negligible)

so  $\left(\frac{\Delta \eta}{\eta}\right)_{\text{total}} \approx \left(\left(2 \frac{\Delta d}{d}\right)^2 + 4 \left(\frac{\Delta R}{R}\right)^2\right)^{1/2} \approx 0.53$

So the major source of measurement error is due to errors in the value of the pipe diameter