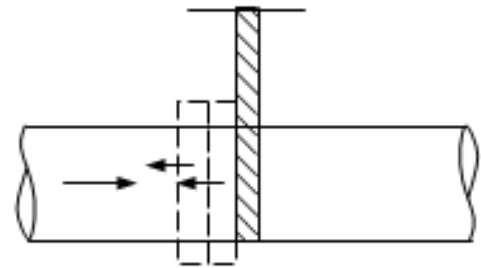
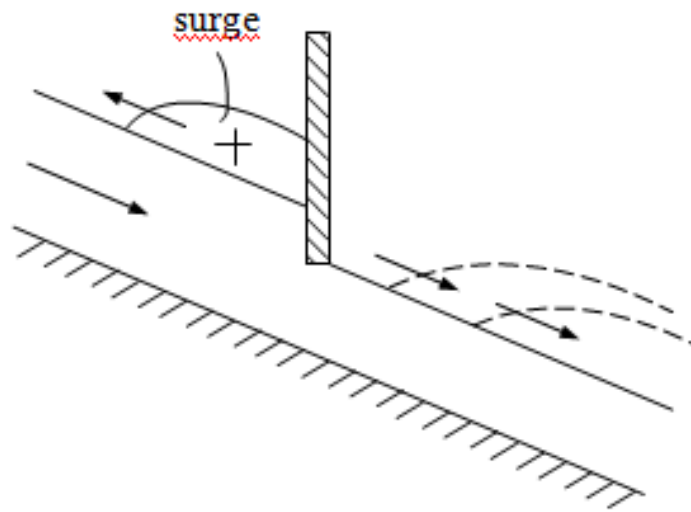


WATER HAMMER (Su darbesi - Su Koçu)

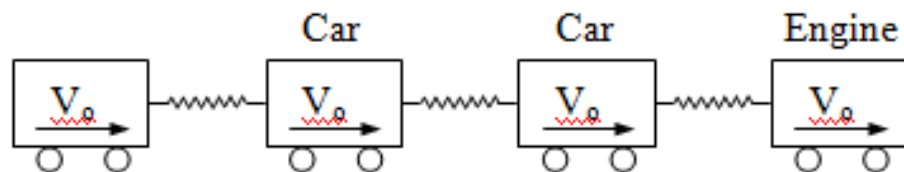


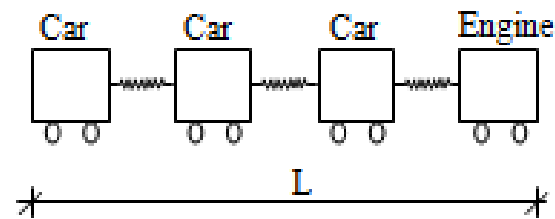
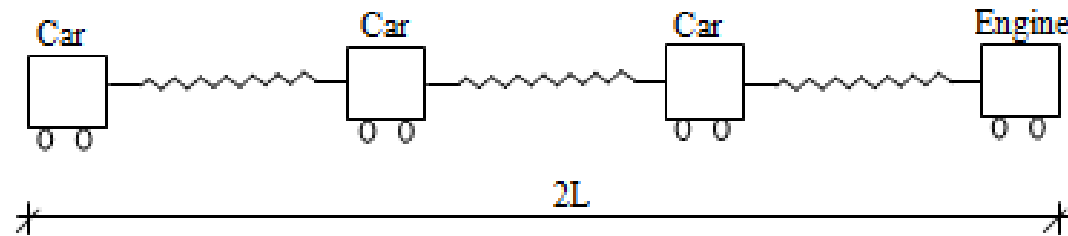
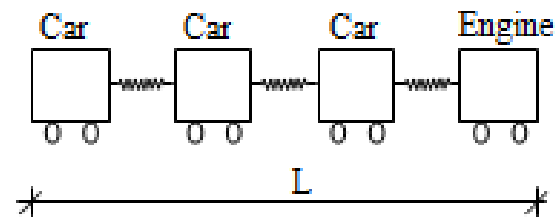
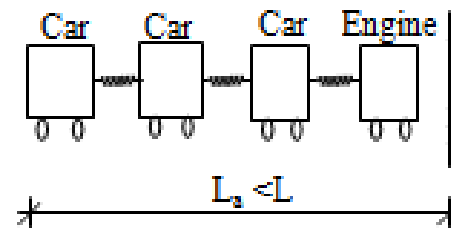
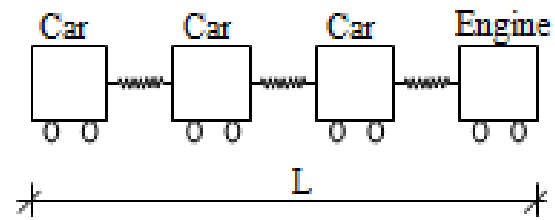
Causes of water hammer;

- Operation of a valve
- Stop or start of a pump or power failure

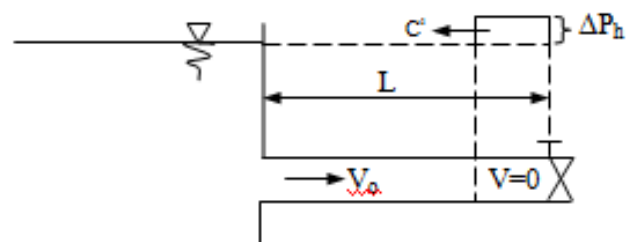
Water Hammer due to Valve Closure:

Freight Train Analogy



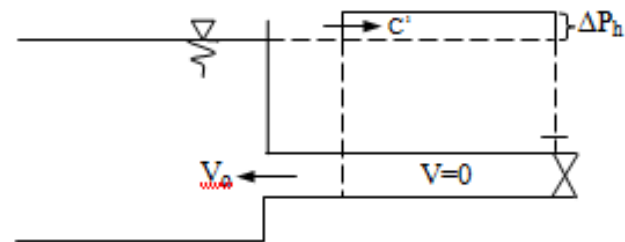


a) pipe expanding



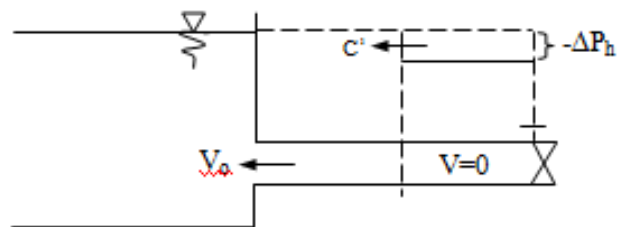
$$0 \leq t \leq L/c'$$

b) pipe returning to normal



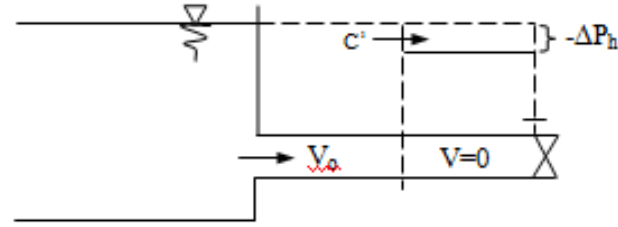
$$L/c' \leq t \leq 2L/c'$$

c) pipe contracting



$$2L/c' \leq t \leq 3L/c'$$

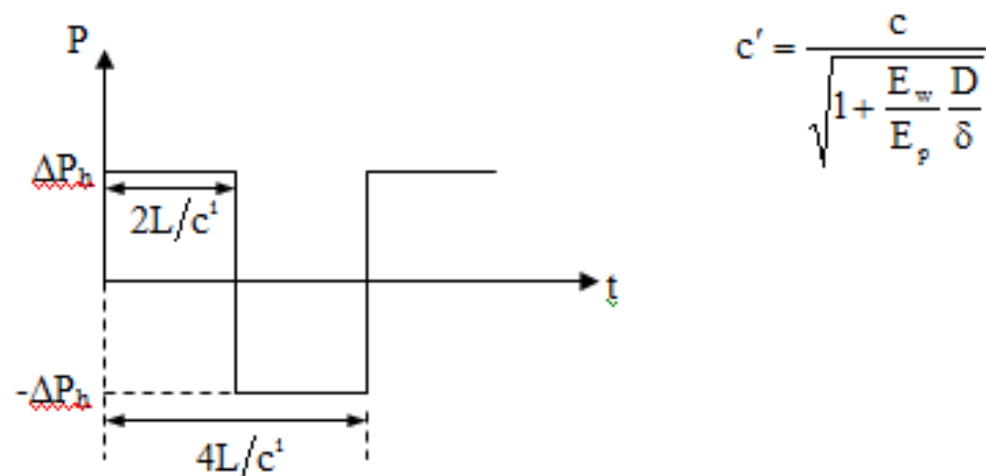
d) pipe returning to normal



$$3L/c' \leq t \leq 4L/c'$$

c' = celerity (velocity) of wave

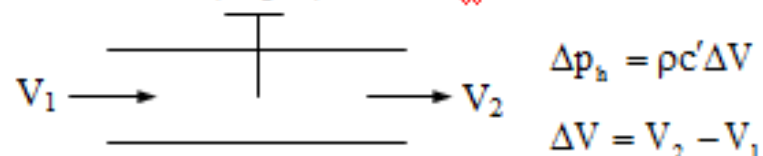
Plot of the pressure variation by time at the valve



where $c = \sqrt{E_w / \rho}$; E_w : elasticity of water, ρ : density of water

E_p : elasticity of pipe; D : diameter of pipe; δ : wall thickness of pipe

Sudden (Rapid) closure $t_c < 2L / c'$ $\longrightarrow \Delta p_h = \rho c' V_0$



Slow closure $t_c > 2L / c'$

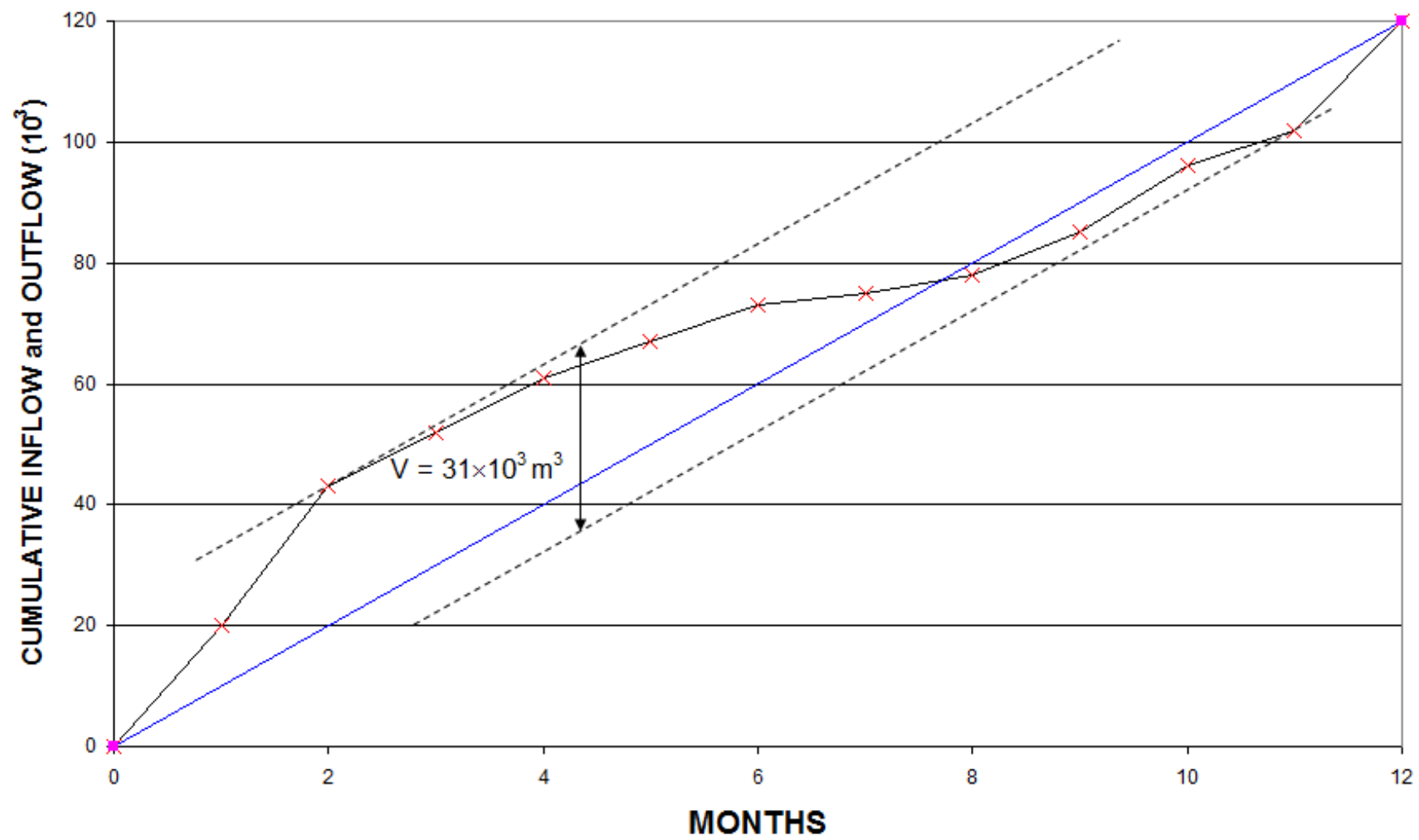
$$\Delta p = \frac{2L \rho V_0}{t_c}$$

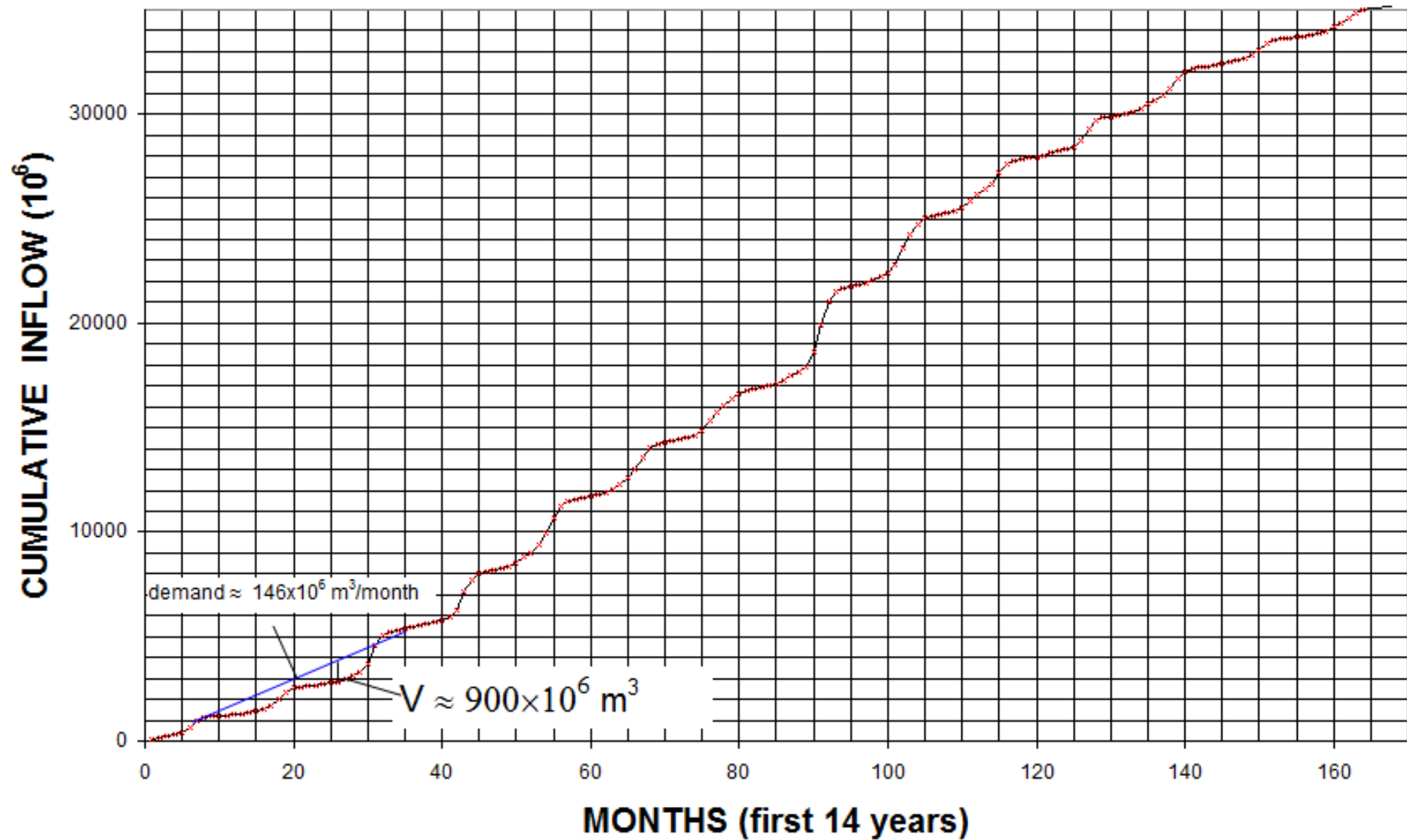
MASS CURVE TABULATION $\times 10^3$

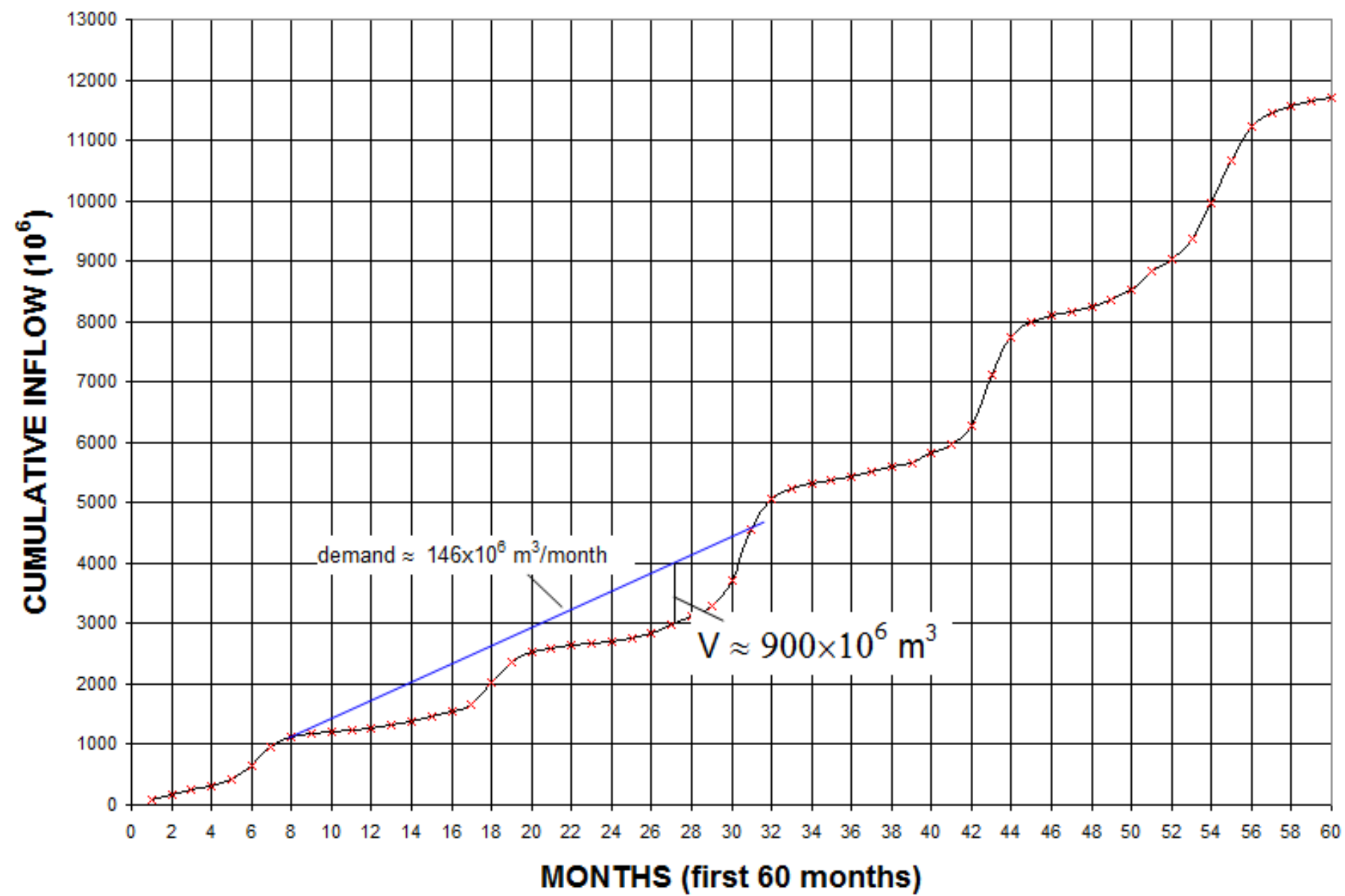
MONTH	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
SUPPLY (S)	20	23	9	9	6	6	2	3	7	11	6	18	120
DEMAND (D)	10	10	10	10	10	10	10	10	10	10	10	10	120
ΣS	20	43	52	61	67	73	75	78	85	96	102	120	
ΣD	10	20	30	40	50	60	70	80	90	100	110	120	
$\Sigma S - \Sigma D$	10	23	22	21	17	13	5	-2	-5	-4	-8	0	
		$\longleftrightarrow$ critical period $\longleftrightarrow$											
RES. CONTENT	18	31	30	29	25	21	13	6	3	4	0	8	
		res. full											

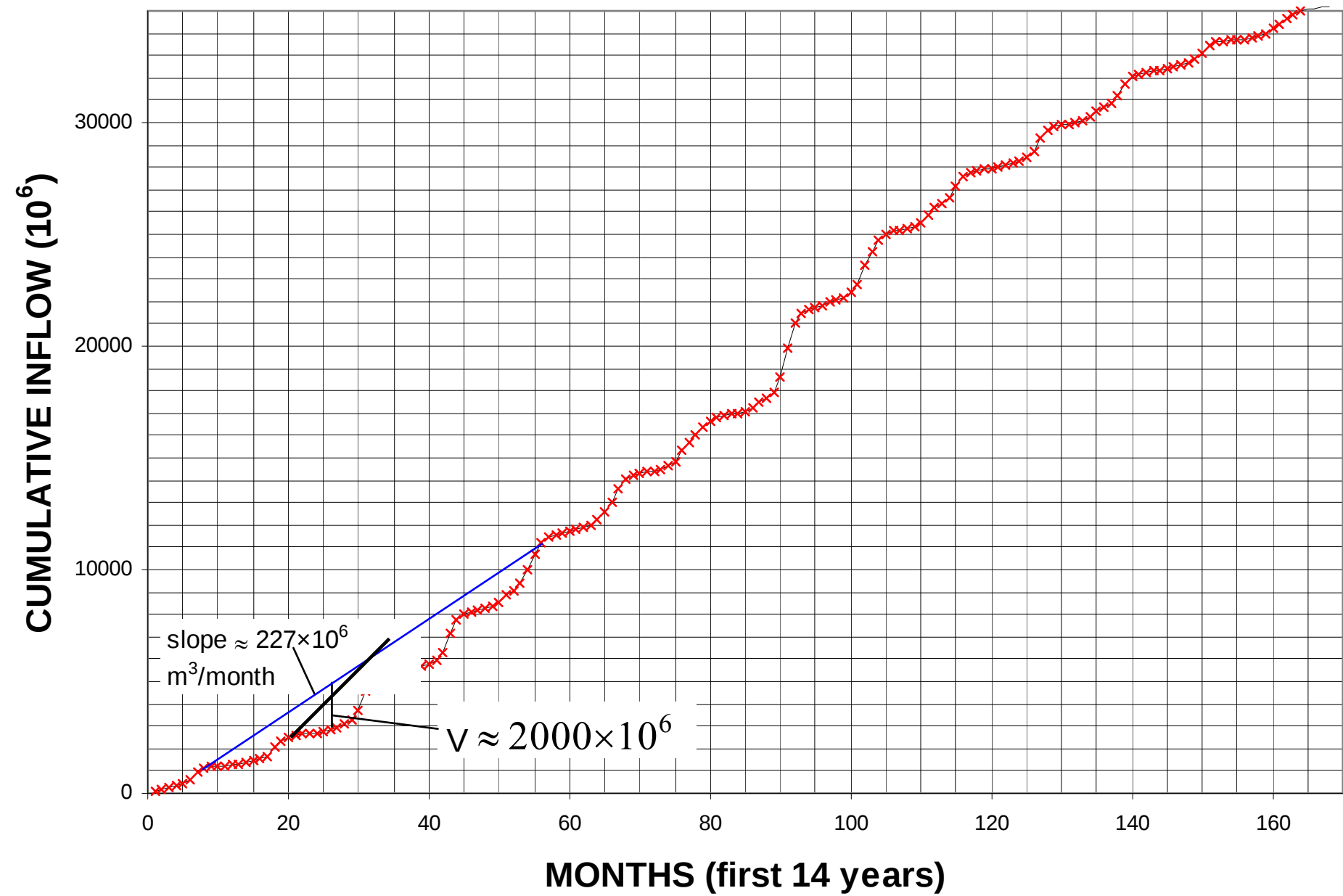
Definitions: Critical period: The period which gives less water than demand.

Safe (firm) yield: maximum amount of water which can be supplied during the critical period.









WATER RESOURCES ENGINEERING

MASS CURVE ANALYSIS

HOMEWORK

The monthly inflow values (m^3/sec) of a river are given in a table given at the back page.

Determine the active storage capacity (volume) for a dam which will be constructed on this river by “Mass Curve” analysis for a safe yield of $146 \times 10^6 \text{ m}^3/\text{month}$.

If the capacity (volume) of the reservoir of the dam is $2000 \times 10^6 \text{ m}^3$, what is the value of “safe yield”?

Do all your calculations separately for;

- i) the data of first 14 years (168 months)
- ii) the data of the last 14 years (168 months)
- iii) the data of the complete series (28 years; 336 months)

Draw the curves on A4 size papers. If you do not use MS Excel then you may use milimetric papers

NO	YEARS	OCTOBER	NOVEMBER	DECEMBER	JANAUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1	1973	32.93	37.6	29.7	23.88	41.34	81.08	117.84	68.78	25.66	10.31	9.02	10.74
2	1974	18.41	23.78	37.77	28.4	39.28	145.67	126.33	68.4	26.7	12.77	10.9	19.19
3	1975	22.7	23.82	52.7	64.28	63.66	159.86	322.7	199.83	67.95	31.55	20.98	22.77
4	1976	27.97	29.3	29.7	56.44	55.37	124.01	322.7	237.53	104.21	41.63	24.31	26.09
5	1977	49.32	58.04	127.38	66.52	140.14	223.7	271.39	215.88	92.25	42	25.61	29.26
6	1978	36.26	34.82	42.25	92.28	143.44	157.62	216.22	162.49	76.43	34.91	23.11	26.01
7	1979	37	40.68	80.33	185.99	150.06	130.74	132.89	100.14	62.16	31.17	20.16	23.47
8	1980	32.26	60.74	87.05	78.09	88.1	268.13	508.27	446.24	167.48	55.44	34.76	35
9	1981	42.98	41.84	56.44	83.32	133.52	323.01	253.26	190.49	108.84	45.36	25.84	29.18
10	1982	35.51	41.45	129.62	135.59	78.55	108.71	206.96	157.26	60.23	30.43	22.96	26.36
11	1983	33.64	32.27	30.38	34.78	43.82	122.89	212.75	149.8	59.07	26.54	18.63	22.81
12	1984	30.47	70.77	82.2	66.89	91.69	131.86	178.8	138.97	51.36	22.66	16.2	20.23
13	1985	25.32	28.34	27.76	44.12	70.69	79.59	138.29	63.18	21.53	10.31	9.02	10.51
14	1986	29.27	32.12	37.77	91.91	69.86	85.93	83.89	60.56	39.01	10.31	9.02	11.78
15	1987	21.43	37.6	48.22	114.68	137.66	147.91	288.37	213.64	98.43	35.28	20.57	24.43
16	1988	29.98	49.94	96.76	75.48	95.68	212.13	325.79	225.21	93.8	42.37	22.96	26.32
17	1989	47.83	62.29	78.84	53.08	48.37	92.28	71.55	38.91	14.67	10.31	9.02	22.27
18	1990	29.27	32.12	37.77	91.91	69.86	85.93	83.89	60.56	39.01	10.31	9.02	11.78
19	1991	21.49	32.43	39.42	27.11	48.22	110.79	156.13	94.14	49.42	15.91	9.02	10.51
20	1992	13.62	29.35	46.58	42.99	47.54	107.26	209.35	169.05	68.26	25.62	18.94	27.49
21	1993	43.56	65.57	93.16	51.45	51.04	115.21	250.43	253.79	77.92	26.16	11.48	53.58
22	1994	28.7	32.12	32.71	56.34	66.74	83.65	107.35	63.15	7.91	10.31	9.02	14.93
23	1995	20.48	45.59	49.43	95.48	75.7	102.83	213.22	147.13	55.47	14.88	9.02	16.46
24	1996	31.93	88.46	53.14	109.11	96.06	231.95	325.03	258.49	74.79	28.95	11.75	22.68
25	1997	55.92	41.2	81.49	87.47	61.87	56.7	197.55	143.91	43.93	10.38	9.02	19.76
26	1998	31.62	50.5	59.78	43.44	53.86	102.92	225.15	147.24	49.27	10.89	9.02	20.4
27	1999	19.73	43.95	122.81	72.03	121.08	115.37	155.39	86.35	30.62	10.31	9.02	14.69
28	2000	21.67	23.32	24.03	54.07	59.12	117.93	263.25	144.39	32.26	12.79	18.34	13.61