Observations

Least count the stop watch.....0.01.....sec

Table 1. Time period of oscillations with different damping currents

Damping current (in Amp)	No. of Oscillations	Time (in sec)	Time period
0	20	36.06	1.803
0.1	20	36.00	1.800
0.2	20	35.91	1.79
0.25	20	35.60	1.78

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Table 2. Maximum values of unidirectional amplitudes as a function of time for different damping

Damping current (A)	Time t (sec)	Amplitude of oscillations (*a*)	*ln* (ϕ_a)	Time t (sec)	Amplitude of oscillations (*b*)	*ln* (ϕ_b)
0	0	ϕ_{a0} = 15	2.71	T/2 = 0.9	ϕ_{b0} = 14.8	2.69
	T = 1.80	ϕ_{a1} = 13.8	2.62	3T/2 = 2.7	ϕ_{b1} = 14.2	2.65
	2T = 3.60	ϕ_{a2} = 13.2	2.58	5T/2 = 4.5	ϕ_{b2} = 14.0	2.64
	3T = 5.4	ϕ_{a3} = 12.8	2.55	7T/2 = 6.3	ϕ_{b3} = 13.8	2.62
	4T = 7.2	ϕ_{a4} = 12.2	2.50	9T/2 = 8.1	ϕ_{b4} = 13.4	2.60
	5T = 9.0	ϕ_{a5} = 12.0	2.48	11T/2 = 9.9	ϕ_{b5} = 13.0	2.56
	6T = 10.8	ϕ_{a6} = 11.8	2.47	13T/2 = 11.7	ϕ_{b6} = 12.8	2.55
	7T = 12.6	ϕ_{a7} = 11.4	2.43	15T/2 = 13.5	ϕ_{b7} = 12.2	2.50
	8T = 14.4	ϕ_{a8} = 11.0	2.40	17T/2 = 15.3	ϕ_{b8} = 11.8	2.47

continued...

Damping current (A)	Time t (sec)	Amplitude of oscillations (*a*)	*ln* (ϕ_a)	Time t (sec)	Amplitude of oscillations (*b*)	*ln* (ϕ_b)
0.0	9T = 16.2	ϕ_{a9} = 10.8	2.38	$\frac{19T}{2}$ = 17.1	ϕ_{b9} = 11.4	2.43
0.1	0	ϕ_{a0} = 15.0	2.71	T/2 = 0.9	ϕ_{b0} = 14.8	2.69
	T = 1.80	ϕ_{a1} = 14.4	2.67	3T/2 = 2.7	ϕ_{b1} = 14.4	2.67
	2T = 3.6	ϕ_{a2} = 14.0	2.64	5T/2 = 4.5	ϕ_{b2} = 13.8	2.62
	3T = 5.4	ϕ_{a3} = 13.4	2.60	7T/2 = 6.3	ϕ_{b3} = 13.4	2.60
	4T = 7.2	ϕ_{a4} = 12.8	2.55	9T/2 = 8.1	ϕ_{b4} = 12.8	2.55
	5T = 9.0	ϕ_{a5} = 12.2	2.50	11T/2 = 9.9	ϕ_{b5} = 12.2	2.50
	6T = 10.8	ϕ_{a6} = 11.8	2.47	13T/2 = 11.7	ϕ_{b6} = 11.8	2.47
	7T = 12.6	ϕ_{a7} = 11.2	2.42	15T/2 = 13.5	ϕ_{b7} = 11.4	2.43
	8T = 14.4	ϕ_{a8} = 10.8	2.38	17T/2 = 15.3	ϕ_{b8} = 11.0	2.40
	9T = 16.2	ϕ_{a9} = 10.0	2.30	19T/2 = 17.1	ϕ_{b9} = 10.4	2.34

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Damping current (A)	Time t (sec)	Amplitude of oscillations (a)	ln (ϕ_a)	Time t (sec)	Amplitude of oscillations (b)	ln (ϕ_b)
0.2	0	ϕ_{a0} = 15.0	2.71	T/2 = 0.90	ϕ_{b0} = 15.0	2.71
	T = 1.79	ϕ_{a1} = 14.0	2.64	3T/2 = 2.68	ϕ_{b1} = 14.0	2.64
	2T = 3.58	ϕ_{a2} = 13.0	2.56	5T/2 = 4.48	ϕ_{b2} = 13.0	2.56
	3T = 5.37	ϕ_{a3} = 12.0	2.48	7T/2 = 6.26	ϕ_{b3} = 12.2	2.50
	4T = 7.16	ϕ_{a4} = 11.4	2.43	9T/2 = 8.06	ϕ_{b4} = 11.2	2.42
	5T = 8.95	ϕ_{a5} = 10.4	2.34	11T/2 = 9.84	ϕ_{b5} = 10.4	2.34
	6T = 10.74	ϕ_{a6} = 10.0	2.30	13T/2 = 11.64	ϕ_{b6} = 9.6	2.26
	7T = 12.53	ϕ_{a7} = 9.0	2.20	15T/2 = 13.42	ϕ_{b7} = 8.8	2.17
	8T = 14.32	ϕ_{a8} = 8.4	2.13	17T/2 = 15.22	ϕ_{b8} = 8.0	2.08
	9T = 16.11	ϕ_{a9} = 7.8	2.05	19T/2 = 17.00	ϕ_{b9} = 7.2	1.97
0.25	0	ϕ_{a0} = 15.0	2.71	T/2 = 0.89	ϕ_{b0} = 14.2	2.65
	T = 1.78	ϕ_{a1} = 13.4	2.60	3T/2 = 2.67	ϕ_{b1} = 13.2	2.58
	2T = 3.56	ϕ_{a2} = 12.2	2.50	5T/2 = 4.45	ϕ_{b2} = 12.0	2.48
	3T = 5.34	ϕ_{a3} = 11.0	2.40	7T/2 = 6.23	ϕ_{b3} = 10.6	2.36
	4T = 7.12	ϕ_{a4} = 10.0	2.30	9T/2 = 8.01	ϕ_{b4} = 9.4	2.24
	5T = 8.9	ϕ_{a5} = 9.0	2.20	11T/2 = 9.79	ϕ_{b5} = 8.4	2.13
	6T = 10.68	ϕ_{a6} = 8.2	2.10	13T/2 = 11.57	ϕ_{b6} = 7.8	2.05
	7T = 12.46	ϕ_{a7} = 7.2	1.97	15T/2 = 13.35	ϕ_{b7} = 6.8	1.92

Table 3. Estimation of Damping constant and resistance for different damping currents

Damping current (A)	$\ln\left(\frac{\phi_{a(n)}}{\phi_{a(n+1)}}\right)$	$\ln\left(\frac{\phi_{b(n)}}{\phi_{b(n+1)}}\right)$	Ave. Logarithmic decrement λ	Time period T (sec) $=2\pi/\omega$	Damping constant $\beta=\lambda/T$	$\omega_{res}=\sqrt{\omega^2-\beta^2}$
0	0.09	0.04	0.03	1.80	0.0167	3.49
	0.04	0.01				
	0.03	0.02				
	0.05	0.02				
	0.02	0.04				
	0.01	0.01				
	0.04	0.05				
	0.03	0.03				
0.1	0.04	0.02	0.04	1.80	0.0222	3.49
	0.03	0.05				
	0.04	0.02				
	0.05	0.05				
	0.05	0.05				
	0.03	0.03				
0.2	0.07	0.07	0.07	1.79	0.0391	3.51
	0.08	0.08				
	0.08	0.06				
	0.05	0.08				
	0.09	0.08				
	0.04	0.08				
0.25	0.09	0.07	0.095	1.78	0.0534	3.53
	0.10	0.10				
	0.10	0.08				
	0.10	0.12				

Table 4. Plot for frequency vs amplitude under forced oscillation (Note: T_1 is to be measured on the eccentric disc and, T_2 on the pendulum.)

Sl. No.	Damping current (A)	Time period of forcing oscillation in sec			Freq. of oscillation (sec^{-1})	Amplitude of oscillation			
		T_1 (s)	T_2 (s)	T_{av} (s)		ϕ_1	ϕ_2	ϕ_3	ϕ_{av}
1	0	8.66	8.88	8.77	0.114	0.6	0.8	0.6	0.67
2		8.06	7.97	8.02	0.125	0.8	1.0	0.8	0.87
3		5.44	5.63	5.54	0.180	0.9	1.2	0.9	1.00
4		3.97	4.06	4.02	0.249	0.8	1.2	0.8	0.93
5		2.94	2.97	3.00	0.333	1.2	1.2	1.2	1.20
6		2.12	2.22	2.17	0.461	2.2	2.4	2.2	2.27
7		1.86	1.90	1.88	0.532	11.8	12	11.8	11.87
8		2.00	2.07	2.04	0.490	2.3	2.5	2.3	2.37
9		1.40	1.47	1.44	0.694	1.3	1.5	1.3	1.37
10		1.31	1.19	1.25	0.800	0.8	0.9	0.8	0.83

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Sl. No.	Damping current (A)	Time period of forcing oscillation in sec			Freq. of oscillation (sec^{-1})	Amplitude of oscillation			
		T_1 (s)	T_2 (s)	T_{av} (s)		ϕ_1	ϕ_2	ϕ_3	ϕ_{av}
1		3.87	3.78	3.82	0.262	0.8	1	0.8	0.87
2		2.69	2.78	2.74	0.365	1.1	1.3	1.1	1.17
3		2.06	1.94	2.00	0.500	2.5	2.6	2.5	2.53
4		1.72	1.65	1.68	0.595	6.8	7	6.8	6.87
5	0.1	1.94	1.91	1.92	0.521	9.8	10	9.8	9.87
6		1.60	1.50	1.55	0.645	6.2	6.6	6.2	6.33
7		1.25 ~~1.06~~	1.20	1.22	0.820	0.8	1	0.8	0.87
8		1.06	0.96	1.01	0.990	0.4	0.6	0.4	0.47

continued...

Sl. No.	Damping current (A)	Time period of forcing oscillation in sec			Freq. of oscillation (sec^{-1})	Amplitude of oscillation			
		T_1 (s)	T_2 (s)	T_{av} (s)		ϕ_1	ϕ_2	ϕ_3	ϕ_{av}
1	0.2	5.87	5.97	5.92	0.169	0.7	0.9	0.7	0.77
2		4.22	4.44	4.33	0.231	0.8	1.1	0.8	0.90
3		2.75	2.68	2.72	0.368	1.6	1.6	1.6	1.60
4		2.25	2.18	2.22	0.450	2	2.2	2	2.07
5		1.81	1.78	1.80	0.556	14.8	15.4	14.8	15.00
6		1.60	1.44	1.52	0.658	1.8	2	1.8	1.87
7		1.25	1.19	1.22	0.820	0.8	1	0.8	0.87
8		1.19	1.15	1.17	0.855	0.6	0.8	0.6	0.67

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Sl. No.	Damping current (A)	Time period of forcing oscillation in sec			Freq. of oscillation (sec^{-1})	Amplitude of oscillation			
		T_1 (s)	T_2 (s)	T_{av} (s)		ϕ_1	ϕ_2	ϕ_3	ϕ_{av}
1		7.22	7.07	7.14	0.140	0.8	0.8	0.8	0.80
2		5.94	5.65	5.80	0.172	0.8	0.9	0.8	0.83
3		4.16	4.13	4.14	0.241	0.9	0.9	0.9	0.90
4		3.22	3.16	3.19	0.313	0.9	1.2	0.9	1.00
5		2.19	2.22	2.20	0.454	1.9	2	1.9	1.93
6	0.25	2	2.06	2.03	0.493	3	3.1	3	3.03
7		1.78	1.66	1.72	0.581	14	14.8	14	14.27
8		1.53	1.47	1.50	0.667	2	2.1	2	2.03
9		1.40	1.34	1.37	0.730	1	1.2	1	1.07

Results:

Damping current (A)	Logarithmic decrement λ	Damping constant β (in Hz)	Resonance frequency ω_{res} (in Hz)		Resonance Amplitude ϕ_{res}	Natural freq. from damped osc. (in Hz) $\omega_0 = \sqrt{\omega^2 + \beta^2}$
			Observed	Estimated		
0	0.03	0.0167	3.34	3.49	11.87	3.49
0.1	0.04	0.0222	3.27	3.49	9.87	3.49
0.2	0.07	0.0391	3.49	3.51	15.00	3.51
0.25	0.095	0.0534	3.65	3.53	14.27	3.53

Precaution

Do not keep the pendulum in resonance condition without damping or with a very low damping for a long time

Error calculation:

Error in estimation of β

$\beta = [\ln\phi_n - \ln\phi_{n+m}]/mT$

$$\frac{\delta\beta}{\beta} = \frac{\delta T}{T} + \frac{1}{m\beta T}\left[\frac{\delta\phi}{\phi_n} + \frac{\delta\phi}{\phi_{n+m}}\right] \quad \text{..(10)}$$

Error in estimation of ω

$$\frac{\delta\omega}{\omega} = \frac{\delta T}{T}$$

Error in estimation of ω_0

$$\frac{\delta\omega_0}{\omega_0} = \frac{\omega\delta\omega + \beta\delta\beta}{\omega^2 + \beta^2} \quad \text{..(11)}$$

ERROR CALCULATION –

$\delta T = 0.01\,sec \qquad \delta\phi = 0.2$

1) ERROR IN ESTIMATION OF β :–

$$\frac{\delta\beta}{\beta} = \frac{\delta T}{T} + \frac{1}{m\beta T}\left[\frac{\delta\phi}{\phi_n} + \frac{\delta\phi}{\phi_{n+m}}\right]$$

For max. error –

$$\frac{\delta\beta}{\beta} = \frac{0.01}{1.78} + \frac{1}{5 \times 0.0534 \times 1.78}\left[\frac{0.2}{15} + \frac{0.2}{9}\right] \quad \begin{pmatrix} n = 1 \\ m = 5 \end{pmatrix}$$

$$= 0.0804$$

∴ Maximum percentage error = 8.04 %

2) ERROR IN ESTIMATION OF ω :–

$$\frac{\delta\omega}{\omega} = \frac{\delta T}{T}$$

For max. error –

$$\frac{\delta\omega}{\omega} = \frac{0.01}{1.78} = 0.0056$$

∴ Max. percentage error = 0.56%

3) ERROR IN ESTIMATION OF ω_0 :–

$$\frac{\delta\omega_0}{\omega_0} = \frac{\omega\delta\omega + \beta\delta\beta}{\omega^2 + \beta^2} = \frac{(3.53)^2(0.0056) + (0.0534)^2(0.0804)}{(3.53)^2 + (0.0534)^2}$$

$$= 0.0056$$

∴ Max. percentage error = 0.53%

1. What is eddy current?
2. Other than the eddy current damping force, what are the other forces those are affecting your experiment?
3. What do you expect if $\omega_0 = \beta$ or $\omega^2 < \beta^2$?
4. What are your conclusions about the phase relationship between the driver and the oscillator below and above resonance?
5. Give a simple example of forced oscillation.
6. What is the physical reason for the large amplitude oscillation at the resonance frequency?
7. Why the resonance curve broadens for higher damping?
8. Check Equation 10 and 11.

Reference :

1. PHYWE LEP 1.3.27 Forced oscillations-Pohl's pendulum
2. The Physics vibrations and waves, H.J. Pain

Graph : Forced oscillation

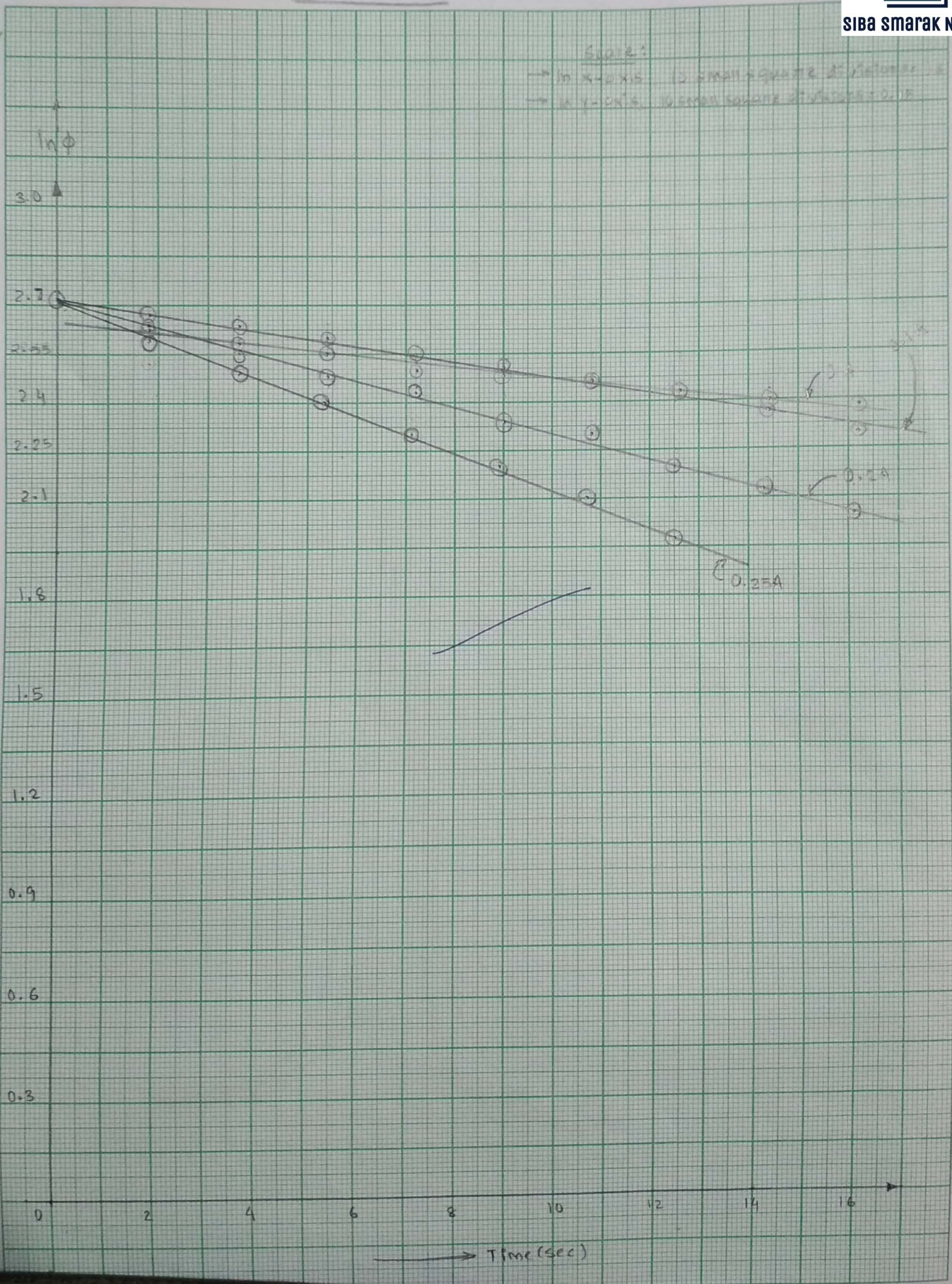
DISCUSSION :

The Pohl's pendulum experiment is a perfect setup to analyse an oscillating body and the effect of a damping current on an external driving force on its motion. Current is internally passed to the spiral wheel of the setup and a damping effect is produced. A motor, externally placed is attached to the axle of the wheel and when switched on, it produces the driven forced oscillations.
One of the major problem faced during experiment was to note the amplitudes on either side.

10/10

18/03/019

ln ϕ vs Time


Scale:
ln ϕ
3.0
2.7
2.55
2.4
2.25
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
2
4
6
8
10
12
14
16
Time (sec)
0.2A
0.25A

Amplitude vs Forcing Frequency