VI-Collected Data:

Part One-Centre of Percussion:

Table-2.1 Collected data for the center of percussion

Trail	Y (cm)	h (cm)	T (second)
1	30.5	31	13.43
2	42.8	34.7	13.93
3	52	35.5	14.15
4	60	38.2	14.26
5	70.7	39.9	15.31

Part Two- Reversible Pendulum:

L = 0.73 (m)

Table-2.2 Collected data for the Reversible pendulum part

Trial	Y1(cm)	T1(second)	Y2 (cm)	T2(second)
1	12	13.35	61	14.86
2	16.5	13.15	56.5	14.61
3	22	13.10	51	14.26
4	23	12.86	50	14.26
5	24.5	13.16	48.5	13.9
6	26	13.1	47	13.98
7	27.5	13.02	45.5	13.8

VIII-Results:

Part One-Centre of Percussion:

Table-2.3 Data processing results for the center of percussion part

Trial	Y(cm)	h(cm)	t(second)	K_A(cm)	L_{equ}(cm)
1	30.5	31	1.343	37.3	44.88
2	42.8	34.7	1.393	40.9	48.21
3	52	35.5	1.415	42.03	49.76
4	60	38.2	1.426	43.93	50.52
5	70.7	39.9	1.531	48.2	58.23

Part Two- Reversible Pendulum:

Table-2.4 Data processing analysis for the Reversible pendulum part

Trial	Y_1(cm)	Y_2 (cm)	h_1(cm)	h_2(cm)	K_{CG}(cm)
1	12	61	21.3596	51.6404	17.6453
2	16.5	56.5	24.1404	48.8596	16.2506
3	22	51	27.5393	45.4607	14.8083
4	23	50	28.1573	44.8427	14.5834
5	24.5	48.5	29.0843	43.9157	14.2704
6	26	47	30.0112	42.9888	13.9885
7	27.5	45.5	30.9382	42.0618	13.7394

Table-2.5 Data processing results for the Reversible pendulum part

Trial	t_1-Theor. (second)	t_1-Exper. (second)	t_1 Percent Error (%)	t_2-Theor. (second)	t_2-Exper. (second)	t_2 Percent Error (%)
1	1.2026	1.3350	11.01	1.5234	1.4860	2.46
2	1.1882	1.3150	10.68	1.4778	1.4610	1.13
3	1.1953	1.3100	9.60	1.4225	1.4260	0.24
4	1.1988	1.2860	7.27	1.4126	1.4260	0.95
5	1.2051	1.2160	0.91	1.3978	1.3900	0.56
6	1.2125	1.310	8.04	1.3832	1.3980	1.07
7	1.2209	1.3020	6.64	1.3687	1.3800	0.83

Table-2.6 Data processing results for the Reversible pendulum part

Trial	g eqn-7 (m/sec.^{2})	g Percent Error (%)	g eqn-8 (m/sec.^{2})	g Percent Error (%)
1	7.9604	18.85	10.31	5.1
2	8.0088	18.36	10.04	2.31
3	8.1671	16.75	9.76	0.49
4	8.5246	13.10	9.63	1.87
5	9.6346	1.79	9.92	1.13
6	8.4039	14.33	9.60	2.11
7	8.6259	12.07	9.65	1.63

Table-2.7 Data processing results for the Reversible pendulum part

From Figure A-1:			
h_1 (cm)	34.6	h_2 (cm)	38.4
Y_1 (cm)	33.43	Y_2 (cm)	39.57

Note :-

To complete table 2-7 , we have to extend the data table 2-2 , (their was an error in taking data , since the data doesn't cover the whole depth of the reversed pendulum , so , we were forced to extend the data table by using data from another group .

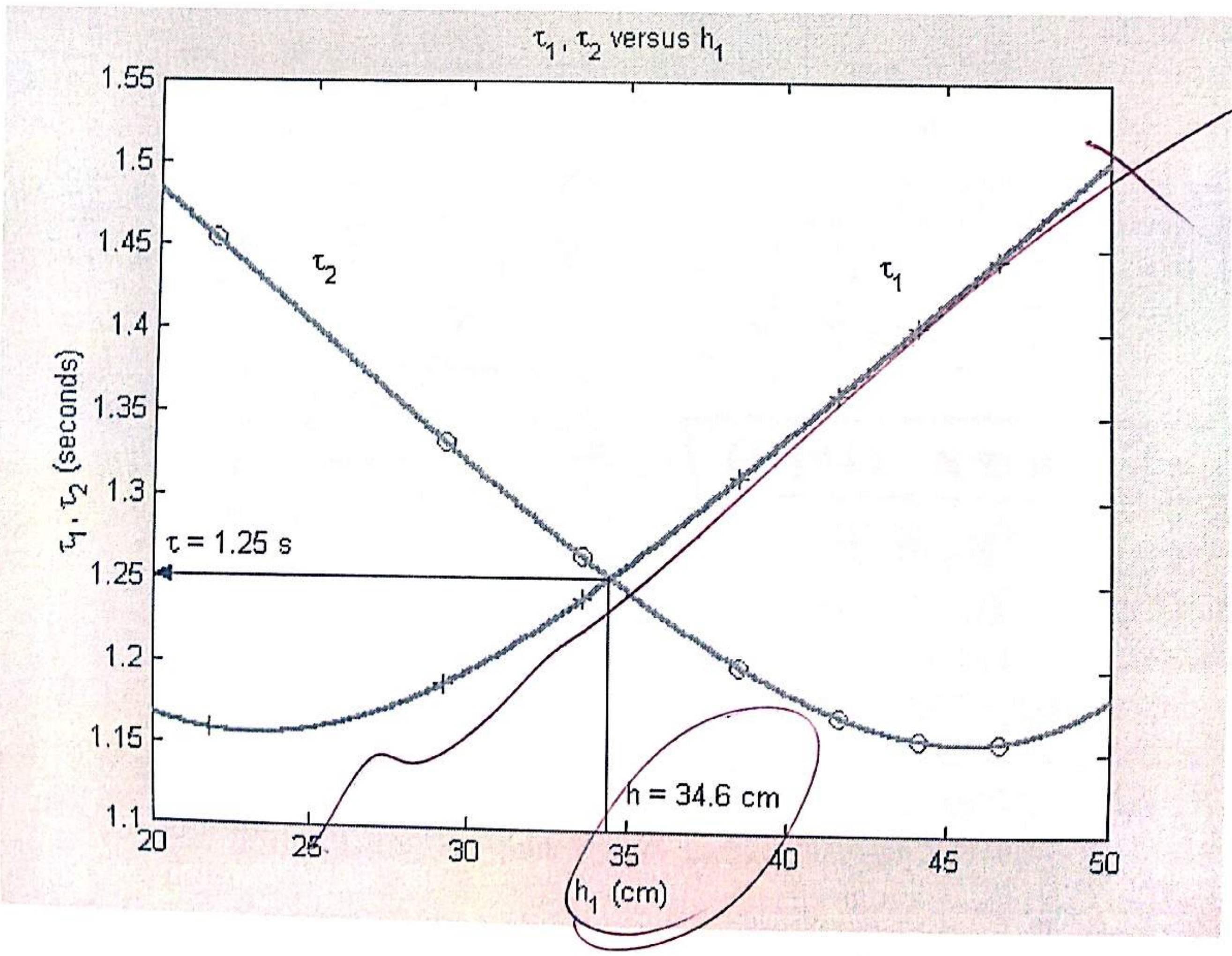
the extension of the data table , and the figure of t1,t2 vs h1 , can be found at the appendix A .

Appendix A :-

Trial	*Y_1 (cm)*	*T_1 (second)*	*Y_2 (cm)*	*T_2 (second)*
1	54	15.00	15	12.00
2	50	14.00	19	12.00
3	46	13.50	23	12.25
4	41	13.00	28	12.50
5	33	12.50	36	13.00
6	26	12.30	43	14.00
7	14	12.00	55	15.00

Table A-1 : extended data for part II .

Figure A-1 : T1 &T2 vs h1 .



sample of caculations :-

* part I :-

* Tabel 2-3 :-

For Trail ① :-

$Y = 30.5$ cm , $h = 31$ cm , $T = 13.43$ sec

1. $\tau = \frac{T}{10} \Rightarrow t = \frac{13.43}{10} = 1.343$ sec ⋇

2. $K_A \rightarrow$ From eqn. 5 :- $\tau = 2\pi \sqrt{\frac{K_A^2}{gh}}$

Then $K_A = \sqrt{\frac{\tau^2 gh}{4\pi^2}} = \sqrt{\frac{(1.343)^2 (9.81)(31)(100)}{4 * \pi^2}} = 37.27$ cm ⋇

(100) → to change From $m/s^2 \rightarrow cm/s^2$

3. $L_{eq} \rightarrow$ From eqn 6 :- $L_{eq} = \frac{K_A^2}{h}$

$\therefore L_{eq} = \frac{(37.3)^2}{31} = 44.88$ cm

⋇

Sample of calculations :-

* part 2 :

* Table 2.4 :-

- For Trail 1 :-

$Y_1 = 12$ cm , $Y_2 = 61$ cm , $L = 0.73$ m , $m = 1.1$ Kg , $M = 0.68$

- From eqn 9, 10 :-

1) $h_1 = \dfrac{\frac{ML}{2} + mY_1}{M + m} = \dfrac{\frac{(0.68)(73)}{2} + (1.1)(12)}{1.1 + 0.68} = 21.36$ cm #

2) $h_2 = \dfrac{\frac{ML}{2} + mY_2}{M + m} = \dfrac{\frac{(0.68)(73)}{2} + 1.1(61)}{1.1 + 0.68} = 51.64$ cm #

- From eqn 11 :-

3) $K_{CG} = \sqrt{\dfrac{M\left(\frac{L^2}{12} + \left(\frac{L}{2} - h_1\right)^2\right) + m\left(Y_1 - h_1\right)^2}{M + m}}$

$= \sqrt{\dfrac{0.68\left(\frac{73^2}{12} + \left(\frac{73}{2} - 21.36\right)^2\right) + 1.1\left(12 - 21.36\right)^2}{0.68 + 1.1}}$

$= 17.65$ cm #

Tabel 2.5 :-

nil 1 :-

$T_1 = 13.35$ sec , $T_2 = 14.86$ sec , $K_{CG} = 17.6453$ cm , $h_1 = 21.3596$ cm , $h_2 = 51.6404$ cm , $g = 9.81$ m/s²

$$\tau_{1\,exp} = \frac{T_1}{10 \text{ cycles}} = 1.3350 \text{ sec}$$ #

$$\tau_{2\,ex} = \frac{T_2}{10 \text{ cycles}} = 1.4860 \text{ sec}$$ #

From eqn 7 and 8 :-

$$\tau_{1\,th} = 2\pi\sqrt{\frac{K_{CG}^2 + h_1^2}{g h_1}} = 2\pi\sqrt{\frac{(17.6453)^2 + (21.3596)^2}{(9.81)(21.3596) * 100}}$$

$$= 1.20258 \text{ sec}$$ #

this was introduced to change m/s² to → cm/s²

$$\tau_{2\,th} = 2\pi\sqrt{\frac{K_{CG}^2 + h_2^2}{g h_2}} = 2\pi\sqrt{\frac{(17.6453)^2 + (51.6404)^2}{(9.81)(51.6404)(100)}}$$

$$= 1.52342 \text{ sec}$$ #

③ percent error % :-

$$E_{r_1} = \frac{|\tau_{th_1} - \tau_{exp_1}|}{\tau_{th_1}} * 100\% = \frac{|1.2026 - 1.335|}{1.2026} * 100\%$$

$$= 11.01\% \quad \#$$

$$E_{r_2} = \frac{|\tau_{th_2} - \tau_{exp_2}|}{\tau_{th_2}} * 100\% = \frac{|1.5234 - 1.4860|}{1.5234} * 100$$

$$= 2.455\% \quad \#$$

Table 2.6 :-

~~Trail / V /~~

eqn 7, 8 :- $\tau_1 = 2\pi \sqrt{\frac{K_{CG}^2 + h_1^2}{g h_1}} \rightarrow g_{eq7} = (4\pi^2) \frac{K_{CG}^2 + h_1^2}{\tau_{1exp}^2 h_1}$ — (a)

$\tau_2 = 2\pi \sqrt{\frac{K_{CG}^2 + h_2^2}{g h_2}} \rightarrow g_{eq8} = (4\pi^2) \frac{K_{CG}^2 + h_2^2}{\tau_{2exp}^2 h_2}$ — (b)

For Trail V :-

$\tau_{1exp} = 1.335$ sec , $\tau_{2exp} = 1.486$ sec , $K_{CG} = 17.6453$ cm

$h_1 = 21.3596$ cm , $h_2 = 51.6404$ cm

$$g_{eq7} = 4\pi^2 \frac{(17.6453)^2 + (21.3596)^2}{(1.335)^2 (21.3596)} * 10^{-2} = 7.96036 \text{ m/s}^2$$

(to change from cm to m)

$$g_{eq8} = 4\pi^2 \frac{(17.6453)^2 + (51.6404)^2}{(1.486)^2 (51.6404)} * 10^{-2} = 10.310 \text{ m/s}^2$$

Error persant % :- $E_{g7} = \frac{|9.81 - g_{eq7}|}{9.81} * 100\%$

$$= \frac{|9.81 - 7.9604|}{9.81} * 100\% = 18.85\%$$

$$E_{g_8} = \frac{|9.81 - g_{e_8}|}{9.81} * 100\% = \frac{|9.81 - 10.31|}{9.81} * 100\%$$

$$= 5.0968\% \quad \#$$

---

* Table 2-7 :-

- From the plot of τ_1 and τ_2 with h_1 "Figure A-1" in Appendix A.

$\tau_1 = \tau_2 = 1.25$ sec , $h_1 = 34.6$ cm

Then :-

① From equation 7 and 8 :- $\frac{K_{GC}^2 + h_1^2}{h_1} = \frac{K_{CG}^2 + h_2^2}{h_2}$

② we Know that $h_1 + h_2 = L$

$\therefore 34.6 + h_2 = 73$ cm $\rightarrow h_2 = 38.4$ cm #

③ eqn 9 :- $h_1 = \frac{\frac{ML}{2} + mY_1}{M + m}$ → Then $Y_1 = \frac{h_1(M + m)}{m} - \frac{ML}{2m}$

$\therefore Y_1 = \frac{34.6(0.68 + 1.1)}{1.1} - \frac{(0.68)(73)}{2(1.1)} = 33.43$ cm #

* Table 2-7 :-

1) eqn 10 :-

$$h_2 = \frac{\frac{ML}{2} + m Y_2}{M + m} \xrightarrow{\text{Then}} Y_2 = \frac{h_2(M+m)}{m} - \frac{ML}{2m}$$

$$\therefore h_2 = \frac{(38.4)(1.1+0.68)}{1.1} - \frac{(0.68)(73)}{2(1.1)}$$

$$= 39.57 \text{ cm } \#$$

* OR $Y_1 + Y_2 = L$

$$Y_2 = 73 - 33.43 = 39.57 \text{ cm } \#$$

Conclusion

1- What is the physical meaning of the equivalent length of the compound pendulum?

The length of a simple pendulum that gives the same period that a compound pendulum gives and thus the same natural frequency.

2- One of the important employments of the concept of the centre of percussion in engineering is found in the automobile, by the proper selection of the positions of the front and rear axles relative to each other, how would you explain that?

If the front wheel had a shock or bump the passengers will not feel any reactions if the center of percussion of the vehicle is near the rear axle. Similarly, if the rear wheels strike a bump, no reaction will be felt at the front axle if the center of percussion is located near the front axle.

3- Comment on your observations concerning the reaction at the pivot point of the compound pendulum, when it has been hit at its centre of percussion compared to other points?

- When the pendulum was hit on point upper the centre of percussion, there was rotation and translational displacement at the pivot point to the right (i.e. axial reaction existed).
- When it was hit below the centre of percussion, there was rotation and translational displacement to the left (i.e. opposed axial reaction existed).
- when the pendulum is hit at the centre of percussion, only rotation at pivot point existed due to moment effect and the axial reaction is zero because there was no displacement in axial direction.

4-Name the major sources of errors in the experiment and comment briefly on the effect of each one on the results obtained?

- Human's error in measuring: Length and time.
- Frictional losses due to air resistance.
- The vibration of the base could affect on the oscillation of the pendulum.

5-In the reversible pendulum part of the experiment, the effect of the knifes fixed at both ends of the bar has not been Considered in the determination of h_1, h_2 & K_{CG}. Consider any case from *Table-2.2*, and recalculate the corresponding parameters with these knifes included, and find the resulted error for each parameter? *(The mass of each knife is $M_K = 0.21$ kg).*

- **Before considering the mass of the knife " M_K":**

Trial	Y_1 (cm)	T_1 (second)	Y_2 (cm)	T_2 (second)	h_1 (cm)	h_2 (cm)	k_{CG}
4	23	12.86	50	14.26	28.1573	44.8427	14.5834

$$\frac{\frac{ML}{2} + m Y_1 + M_K L}{M + m + M_K}$$

$$= \frac{\frac{(0.68)(0.69)}{2} + (1.1)(0.23) + (0.21)(0.69)}{0.68 + 1.1 + 0.21} = 31.8 \text{ cm}$$

$$\text{Error } \% = \frac{31.8 - 28.1573}{31.8} * 100\% = 11.45\%$$

$$h_2 = L - h_1 = 69 - 31.8 = 37.2 \text{ cm}$$

$$\text{Error } \% = \left| \frac{37.2 - 44.8427}{37.2} \right| * 100\% = 20.54\%$$

$$K_{CG} = \sqrt{\frac{M\left(\frac{L^2}{12} + \left(\frac{L}{2} - h_1\right)^2\right) + m(Y_1 - h_1)^2 + M_K(L - h_1)^2}{M + m + M_K}}$$

$$= \sqrt{\frac{(0.68)\left(\frac{(0.69)^2}{12} + \left(\frac{0.69}{2} - 0.318\right)^2\right) + 1.1(0.23 - 0.318)^2 + 0.21(0.69 - 0.318)^2}{0.21 + 0.68 + 1.1}}$$

$$= 18.1 \text{ cm}$$

$$\text{Error } \% = \frac{18.1 - 14.5834}{18.1} * 100\% = 19.43\%$$

Application:

Swordmaking :

The center of percussion of a sword is the point on the blade where cutting produces the least hand shock. It is also the division between the weak and middle sections of the blade.

Like the center of balance of a sword, the center of percussion can be moved by employing a heavier pommel or changing the mass distribution of the blade.

One of the vibrational nodes of the second harmonic of a vibrating sword (the node closest to the tip) is also often (mistakenly) referred to as the center of percussion. The significance of the vibrations about this mode have been contested as having little relevance to sword physics.

So-called "blade harmonics" are a commonly misunderstood concept. The common belief is that a sword must be "harmonically balanced" in order to cut properly, because the vibrations would otherwise interrupt the line and power of the cut. As explained above, this proposition is false: the vibrations caused by a sword cut are almost unnoticeable except as a mild stinging to the hands even in blades that lack this quality. It has also been demonstrated that the object the sword cuts through serves to further reduce the intensity of any vibration, making it even less noticeable.

Many experts speculate that harmonic balance is merely a byproduct of proper construction and balancing, rather than an intentional quality added to weapons. Unfortunately, some sword vendors advertise "secret techniques" of harmonic balancing in an attempt to "prove" the superiority of their products. This only serves to amplify the false impressions of the value of harmonic balance by seeming to lend them legitimacy.