(SEM-2)

Particulars of The Experiments Performed

Date	Serial No.	Experiment No.	Subject / Experiment	Page No.	Signature	Remarks
24/3/2023	1.	E12	Magnetic Field Mapping using Helmholtz Coils.			
31/3/2023						
11/4/2023	2.	03	Measurement of effective spring constant of a string-mass assembly using two coupled pendula.			
27/4/2023						
18/5/2023	3.	M3	Verification of Newton's Second Law of Motion, by Air Track.			
25/5/2023						
1/6/2023	4.	M6	Reversible pendulum. Kater's pendulum.			

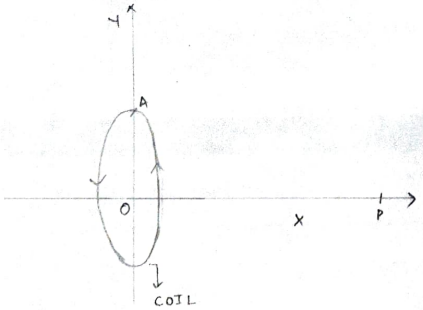


DIAGRAM OF AXIS OF A COIL WITH CURRENT

Topic : E12

PIONEER

Page :

Date : 24 / 3 / 2023

AIM

We will perform the following studies with the set up.

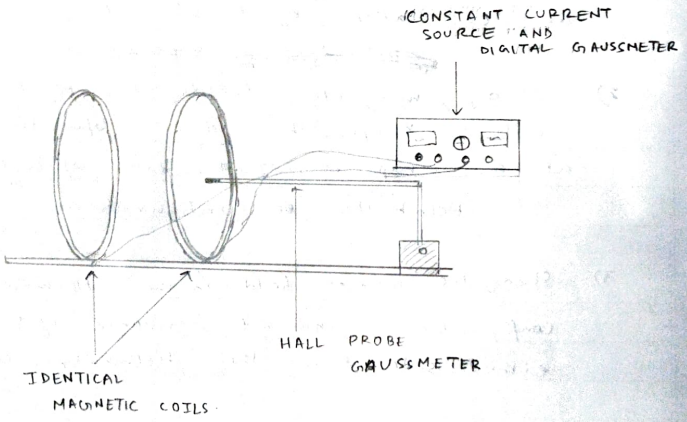
1) Study of magnetic field due to one coil and calculation of its diameter.

2) Study magnetic fields due to two coils by keeping the dist. b/w the coils at a, where a is the radius of coil, i.e at Helmholtz configuration.

3) Study the magnetic field in the Helmholtz configuration and at a distance of 5cm on either side from the Helmholtz configuration.

WORKING FORMULA.

The magnetic field intensity (B) at a point 'P', lying on the axis of a circular coil 'AB' of radius 'a' having 'n' turns at a distance 'x' from the centre 'O' of coil is given by,



EXPERIMENTAL SET-UP

Topic :

PIONEER®

Page :

Date : / /

$$B = \frac{\mu_0}{4\pi} \frac{2\pi n I a^2}{(a^2+x^2)^{3/2}}.$$

I = current flowing through the coil.

μ_0 = Permeability of free space.

= $4\pi \times 10^{-7}$ H/m.

Unit of B = T or Wb/m^2.

Now, when $x = 0$, Magnetic Field is maximum at the centre O of the coil.

$$B = \frac{\mu_0}{4\pi} \frac{2\pi n I}{a^2} = \frac{\mu_0 n I}{2a}.$$

The direction of the magnetic intensity at P is along $\vec{OP}$ produced if the current flows through the coil in the anti-clockwise direction as seen from P. If the direction of current is clockwise the field at P is along $\vec{PO}$.

Topic :

PIONEER®

Page :

Date : / /

DATA AND CALCULATION.

(a) Calculating Diameter of coil.

We set,

$I = 400mA.$

$n = 500.$

And due to a single coil, we obtained.

$B_{max} = 10.9\ G.$

$$\therefore B(G) = \frac{4\pi \times 10^{-7} n I}{2a} \times 10^4$$

$$\therefore \text{diameter} = 2a = \frac{4 \times 3.14 \times 10^{-7} \times 500 \times 400 \times 10^{-3} \times 10^4}{10.9}$$

$$= 0.2304\ m$$

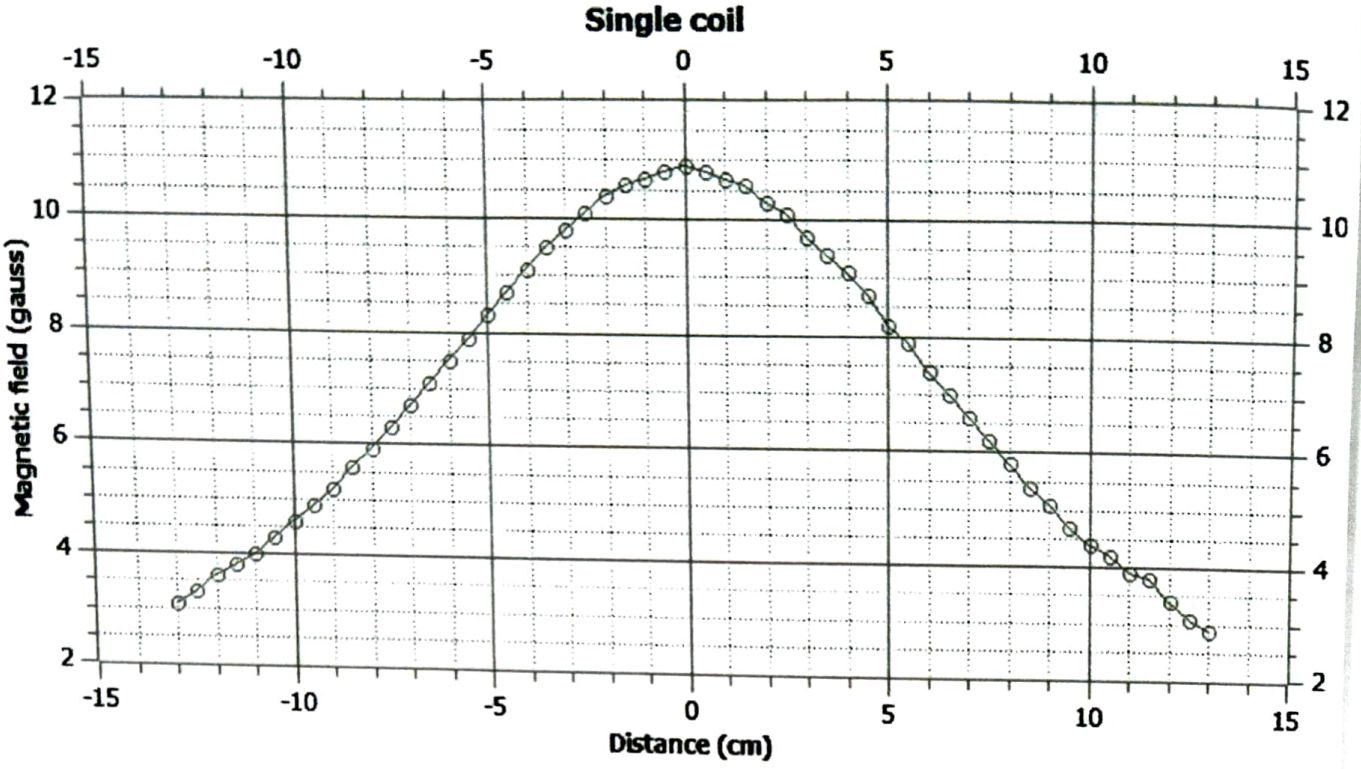
$$= \underline{23.04} \approx \underline{23\ cm}$$

Ans

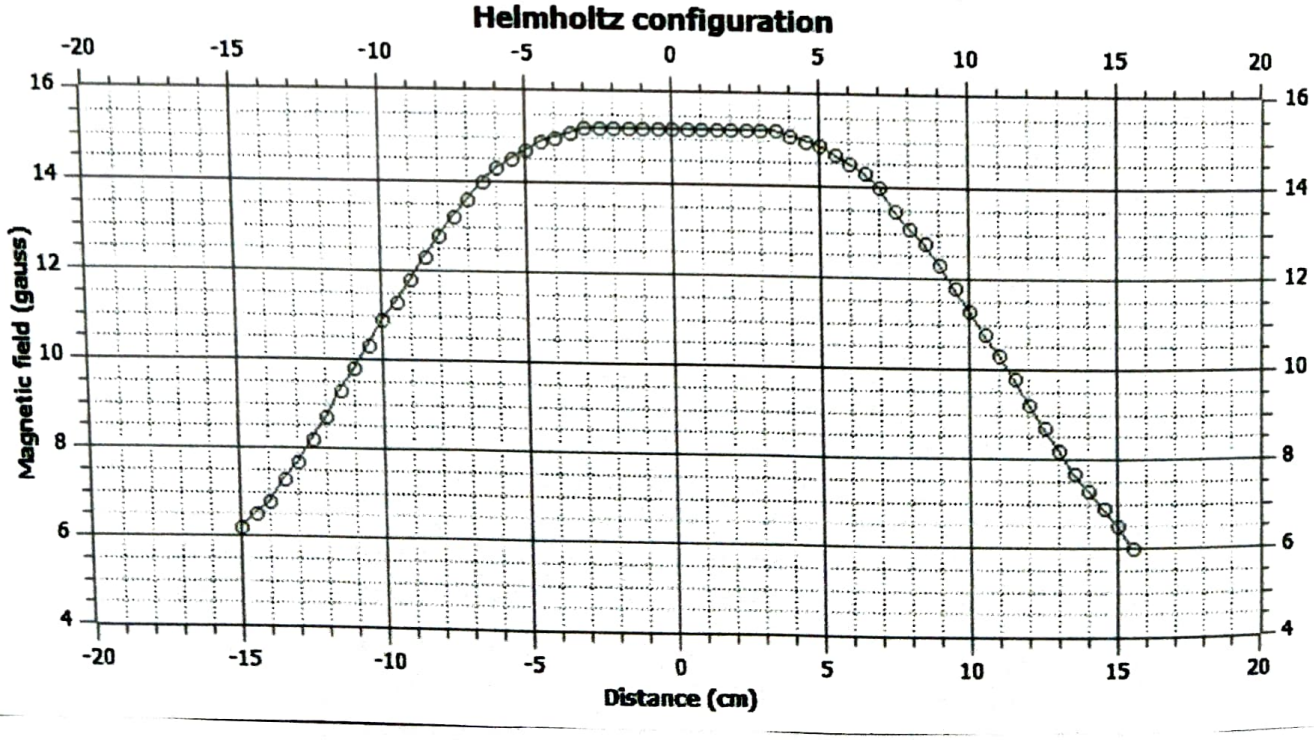
(b) Calculating Helmholtz Configuration.

It occurs when the dist. ' ' between the coils is equal to the radius of the coil. $= \frac{23}{2} = \underline{11.5cm}$

The graphs of our data were plotted in the next page.


Single coil
Magnetic field (gauss)
Distance (cm)
-15
-10
-5
0
5
10
15
2
4
6
8
10
12

(A)


Helmholtz configuration
Magnetic field (gauss)
Distance (cm)
-20
-15
-10
-5
0
5
10
15
20
4
6
8
10
12
14
16

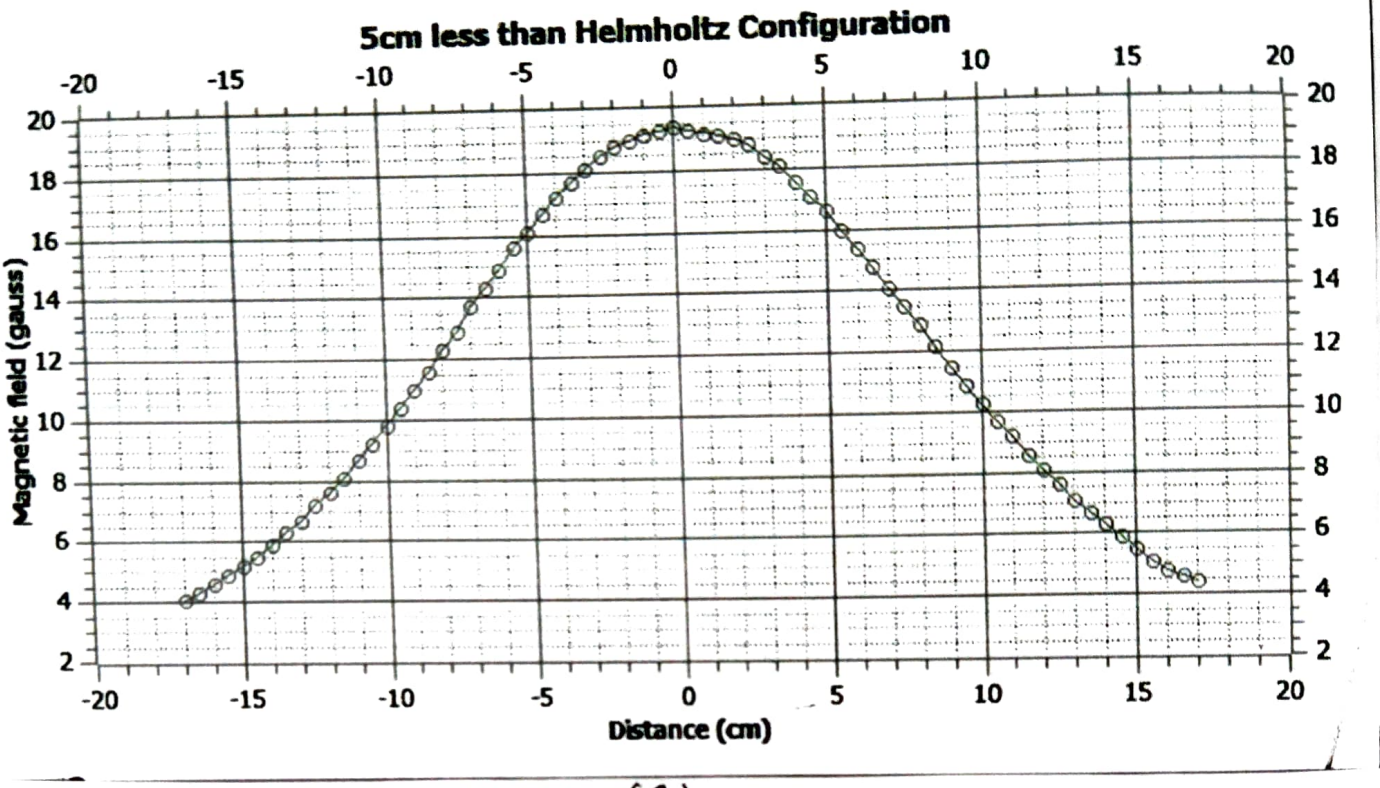
(B)

A) Due to a Single Coil

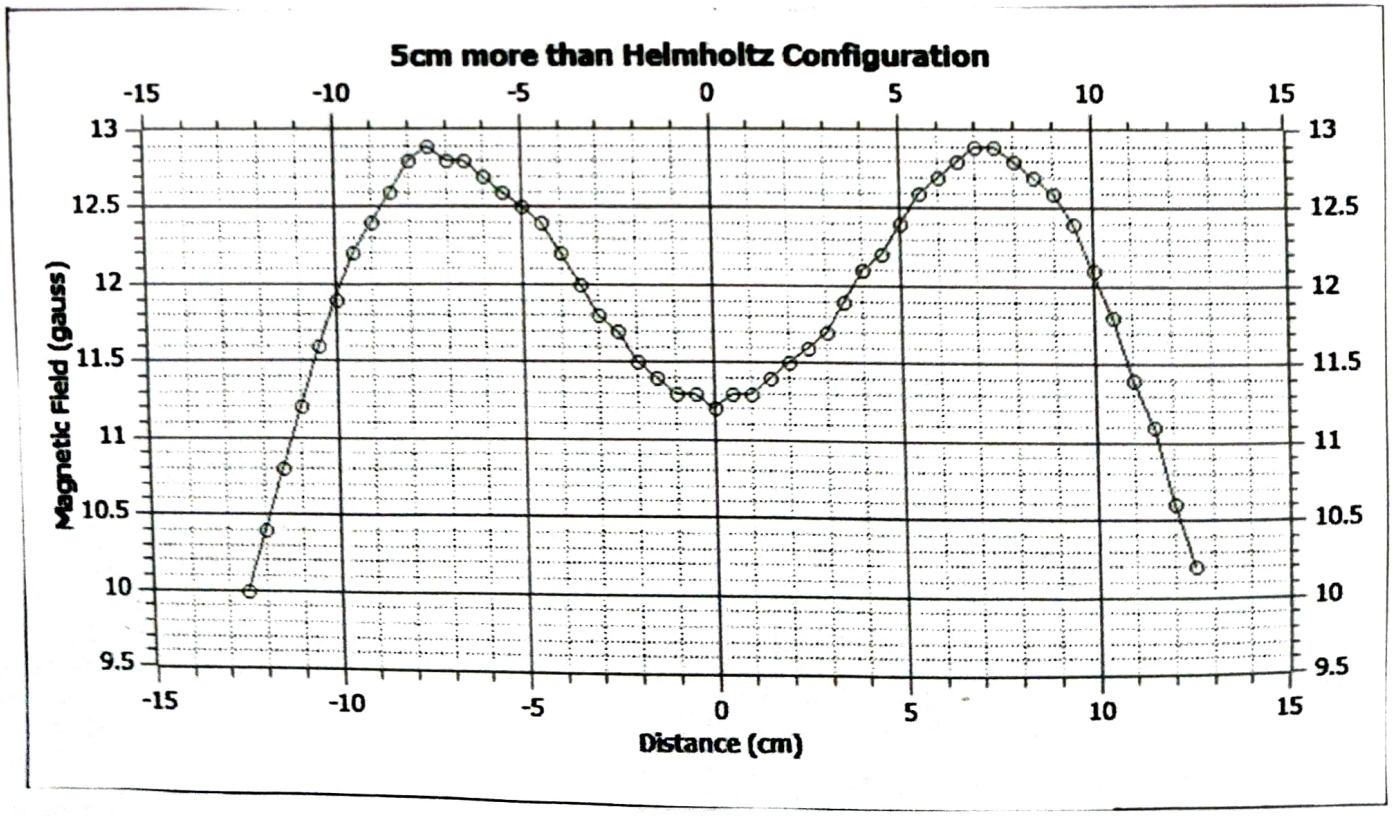
Magnetic Field B (in Gauss)	x (in cm)
3.1	-13
3.3	-12.5
3.6	-12
3.8	-11.5
4	-11
4.3	-10.5
4.6	-10
4.9	-9.5
5.2	-9
5.6	-8.5
5.9	-8
6.3	-7.5
6.7	-7
7.1	-6.5
7.5	-6
7.9	-5.5
8.3	-5
8.7	-4.5
9.1	-4
9.5	-3.5
9.8	-3
10.1	-2.5
10.4	-2
10.6	-1.5
10.7	-1
10.8	-0.5
10.9	0
10.8	0.5
10.7	1
10.6	1.5
10.3	2
10.1	2.5
9.7	3
9.4	3.5
9.1	4
8.7	4.5
8.2	5
7.9	5.5
7.4	6
7	6.5
6.6	7
6.2	7.5
5.8	8
5.4	8.5
5.1	9
4.7	9.5
4.4	10
4.2	10.5
3.9	11
3.8	11.5
3.4	12
3.1	12.5
2.9	13

B) At Helmholtz Config.

Magnetic Field B (in Gauss)	x (in cm)
6.2	-15
6.5	-14.5
6.8	-14
7.3	-13.5
7.7	-13
8.2	-12.5
8.7	-12
9.3	-11.5
9.8	-11
10.3	-10.5
10.9	-10
11.3	-9.5
11.8	-9
12.3	-8.5
12.8	-8
13.2	-7.5
13.6	-7
14	-6.5
14.3	-6
14.5	-5.5
14.7	-5
14.9	-4.5
15	-4
15.1	-3.5
15.2	-3
15.2	-2.5
15.2	-2
15.2	-1.5
15.2	-1
15.2	-0.5
15.2	0
15.2	0.5
15.2	1
15.2	1.5
15.2	2
15.2	2.5
15.2	3
15.2	3.5
15.1	4
15	4.5
14.9	5
14.7	5.5
14.5	6
14.3	6.5
14	7
13.5	7.5
13.1	8
12.8	8.5
12.3	9
11.8	9.5
11.3	10
10.8	10.5
10.3	11
9.8	11.5
9.2	12
8.7	12.5
8.2	13
7.7	13.5
7.3	14
6.9	14.5
6.5	15


5cm less than Helmholtz Configuration
Magnetic field (gauss)
Distance (cm)
-20
-15
-10
-5
0
5
10
15
20
2
4
6
8
10
12
14
16
18

(C)


5cm more than Helmholtz Configuration
Magnetic Field (gauss)
Distance (cm)
-15
-10
-5
0
5
10
15
9.5
10
10.5
11
11.5
12
12.5
13

(D)

C) $5cm$ less than Helmholtz Config

Magnetic Field B (in Gauss)	x (in cm)
4.1	-17
4.3	-16.5
4.6	-16
4.9	-15.5
5.2	-15
5.5	-14.5
5.9	-14
6.3	-13.5
6.7	-13
7.2	-12.5
7.6	-12
8.1	-11.5
8.7	-11
9.2	-10.5
9.8	-10
10.4	-9.5
11	-9
11.6	-8.5
12.3	-8
12.9	-7.5
13.7	-7
14.3	-6.5
14.9	-6
15.6	-5.5
16.1	-5
16.7	-4.5
17.2	-4
17.7	-3.5
18.1	-3
18.5	-2.5
18.8	-2
19	-1.5
19.2	-1
19.3	-0.5
19.4	0
19.3	0.5
19.2	1
19.1	1.5
19	2
18.8	2.5
18.4	3
18.1	3.5
17.6	4
17.1	4.5
16.6	5
16	5.5
15.4	6
14.8	6.5
14.1	7
13.5	7.5
12.9	8
12.2	8.5
11.5	9
10.9	9.5
10.3	10
9.7	10.5
9.2	11
8.6	11.5
8.1	12
7.6	12.5
7.1	13
6.7	13.5
6.3	14
5.9	14.5
5.5	15
5.1	15.5
4.8	16
4.6	16.5
4.4	17

D) $5cm$ more than Helmholtz Config.

Magnetic Field B (in Gauss)	x (in cm)
10	-12.5
10.4	-12
10.8	-11.5
11.2	-11
11.6	-10.5
11.9	-10
12.2	-9.5
12.4	-9
12.6	-8.5
12.8	-8
12.9	-7.5
12.8	-7
12.8	-6.5
12.7	-6
12.6	-5.5
12.5	-5
12.4	-4.5
12.2	-4
12	-3.5
11.8	-3
11.7	-2.5
11.5	-2
11.4	-1.5
11.3	-1
11.3	-0.5
11.2	0
11.3	0.5
11.3	1
11.4	1.5
11.5	2
11.6	2.5
11.7	3
11.9	3.5
12.1	4
12.2	4.5
12.4	5
12.6	5.5
12.7	6
12.8	6.5
12.9	7
12.9	7.5
12.8	8
12.7	8.5
12.6	9
12.4	9.5
12.1	10
11.8	10.5
11.4	11
11.1	11.5
10.6	12
10.2	12.5

Topic :

PIONEER

Page :

Date : / /

ERROR ANALYSIS

we had, $B = \frac{\mu_0 n I}{2a}$.

$\Rightarrow$ diameter $= 2a = l = \frac{\mu_0 n I}{B}$

$\therefore$ % Error:

$$\frac{dl}{l} = \frac{dB}{B} + \frac{dI}{I}.$$

$\Rightarrow$ $$\frac{dl}{l} = \frac{0.1}{10.9} + \frac{1}{400}.$$

$$= 0.0116$$

dB, dI are the least count values respectively.

$\therefore$ % Error $= \frac{dl}{l} \times 100 = 1.16\ \%$

CONCLUSION -

In Helmholtz configuration, a region of nearly uniform magnetic field is produced between the two coils. This is also experimentally verified in our experiment, where a uniform constant field, B = 15.2 Gs existed for 6.5 cm.

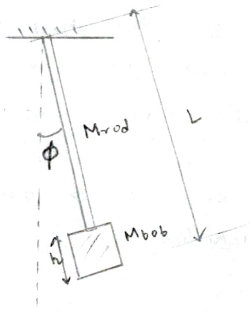
The diameter of the coil obtained from our experiment = (23 ± 1.16 %. cm)

SOURCES OF ERROR

1. The height of the Hall probe Gaussmeter head, might not have remained constant throughout the experiment.

2. Their might be error due to current ~~fluction~~. fluctuation.

3. current leakage due to improper insulation of the coils and resistance of the wires.



(a) Single Pendulum

Topic :

Page :

Date : 11 / 04 / 2023

AIM

The aim of our experiment is to measure the effective spring constant of a string-mass assembly. We denote spring constant ~~Again we~~ measured as K_{expt}.

Further we shall estimate the ~~effective~~ spring constant of same, we denote it as K_{estim}.

Then we will compare the two values.

WORKING FORMULA.

only write formulas

(contd. on Ruled pages).

(a) For ~~single~~ single pendulum the equation of motion can be written as

$$I\ddot{\phi} + \Gamma = 0$$

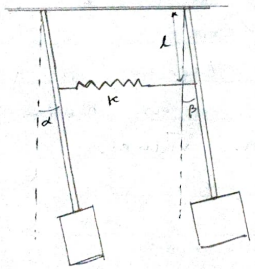
I = Moment of Inertia of Pendulum.

ϕ = Angular displacement

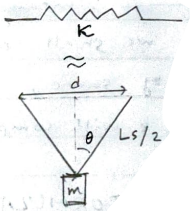
when ϕ is very small, $\sin\phi \approx \phi$

$\therefore$

$$\Gamma = M_{bob} g L \phi + \frac{1}{2} M_{rod} g L \phi$$



(A)



(B)

(b)

(A) Two pendula coupled by a spring

(B) String-mass assembly modelled as a spring.

Topic :

Page :

Date : / /

Calculating MOI of pendulum

$I = I_B + I_R$. $\quad B = Bob, \; R = Rod.$

$= M_{bob} L^2 \left(1 - \frac{h}{2L}\right)^2 + \frac{1}{3} M_{rod} L^2 \left(1 - \frac{h}{L}\right)^2$

$\approx M_{bob} L^2 \left(1 - \frac{h}{L}\right) + \frac{1}{3} M_{rod} L^2 \left(1 - \frac{2h}{L}\right)$

∴ The Angular frequency of oscillation for the single pendulum.

$$\omega_s = \sqrt{\frac{gL\left(M_{bob} + \frac{1}{2} M_{rod}\right)}{I}}$$

$$= \sqrt{\frac{gL M_{eff}}{I}}$$

(b) Two coupled pendula.

Here, (from the diagram)

α, β - Angular displacement of pendula.

l = distance from the top of the pendulum to the point of suspension of spring

$M_{eff} = M_{bob} + \frac{1}{2} M_{rod}$.

OBSERVATIONS AND CALCULATIONS

(Contd. on Plain Page)

(I) Theoretical spring constant (K_{theo} / K_{estim})

$m = (24 \pm 1)g = (24 \times 10^{-3} \pm 10^{-3})\ kg$

$L_s = 17.7 \pm 0.1\ cm$.

$= (17.7 \pm 0.1) \times 10^{-2}\ m$.

$d = 0.11\ m = 11\ cm$.

$g = 9.8\ m/s^2$

$$K_{estim} = \frac{mg}{2} \frac{L_s^2}{(L_s^2 - d^2)^{3/2}}.$$

$$= \frac{24 \times 10^{-3} \times 9.8}{2} \frac{(17.7)^2 \times 10^{-4}}{((17.7)^2 - d^2)^{3/2} \times 10^{-6}}$$

$$= 1.318\ \frac{N}{m}$$

(II) Calculating Moment of Inertia (I)

$$I = M_{bob} l^2 \left(1 - \frac{h}{L}\right) + \frac{1}{3} M_{rod} l^2 \left(1 - \frac{2h}{L}\right)$$

$M_{bob} = 170.86\ g = 170.86 \times 10^{-3}\ kg$

$M_{rod} = 132.09\ g = 132.09 \times 10^{-3}\ kg$

$h = 3cm = 3 \times 10^{-2}\ m$; $L = 85cm = 0.85m$.

Putting values we get,

$I = 148.65 \times 10^{-3}\ kg\ m^2$.

Topic :

PIONEER

Page :

Data : / /

under small angle approximations, we can write the equation of motion as.

$$I\ddot{\alpha} = -M_{eff} g L \alpha - K l^2 (\alpha - \beta)$$

$$I\ddot{\beta} = -M_{eff} g L \beta - K l^2 (\alpha - \beta).$$

Adding & subtracting the above eqns we get,

$$I(\ddot{\alpha} + \ddot{\beta}) = -M_{eff} g L (\alpha + \beta)$$

$$I(\ddot{\alpha} - \ddot{\beta}) = -M_{eff} g L (\alpha - \beta) - 2K l^2 (\alpha - \beta).$$

Here Here,

the $\alpha+\beta$ mode or '+' mode represent the 'in-phase' motion of pendula, whose corresponding natural frequency is 'ω_+'

Similarly $\alpha-\beta$ mode. or, '$-$' mode represent 'out-of-phase' motion, whose natural frequency is 'ω_-'

~~Upon calculating~~

Now, the frequency of in-phase motion ω_+ is identical to that of a single pendulum (ω_s)

i.e $\omega_+ = \omega_s$ = constant throughout our experiment.

(II) Calculating $\omega_s = \omega_+$.

Sl No.	20T(s)	T(s)	$\omega_+ = \frac{2\pi}{T}$ (rad/s)
1	30.20	1.510	4.161
2	30.13	1.507	4.171
3	30.11	1.506	4.173
4	30.25	1.512	4.154

$(\omega_+)_{avg} = 4.165$ rad/s.

Here we have measured time for a' 20 oscillation period, by swinging the pendulum not more than 3cm.

(III) Calculating Experimental spring constant (K_{expt}) for different values of 'l'

(a) $l = 25$ cm.

Table for ω_{beat}.

Sl No.	T(s)	$\frac{2\pi}{T}$ (rad/s)
1	52.19	0.1204
2	52.37	0.1200
3	52.72	0.1192
4	52.44	0.1198

$(\omega_{beat})_{1,avg} = 0.1198$ rad/s.

$\therefore (\omega_-)_1 = (\omega_+) + (\omega_{beat})_1$

$= 4.285$ rad/s

$\therefore (K_{expt})_1 = \frac{I}{2l^2}(\omega_-^2 - \omega_+^2)$

$= \frac{148.65 \times 10^{-3}}{2(0.25)^2}\left((4.285)^2 - (4.165)^2\right)$

$= 1.204$ N/m.

Upon calculating we find,

$$\omega_+ = \omega_s = \sqrt{\frac{M_{eff} g L}{I}}$$

$$\omega_- = \sqrt{\frac{M_{eff} g L + 2Kl^2}{I}}$$

$\Rightarrow$ We will measure this K, experimentally for different values of l.

$\therefore K_{expt} = \frac{I}{2l^2}(\omega_-^2 - \omega_+^2)$.

where, $\omega_- = \omega_+ + \omega_{beat}$.

Theoretical Estimate of spring constant (K_{estim}).

$T = \frac{mg}{2\cos\theta}$

$\therefore$ ~~Ver component of~~ Horizontal component of tension is.

$$F = \frac{mg\tan\theta}{2} = \frac{mg}{2}\frac{d/2}{\sqrt{\frac{L_s^2}{4} - \frac{d^2}{4}}}$$

If we displace by hor. dist. x,

$$F' = \frac{mg}{2}\tan\theta' = \frac{mg}{2}\frac{\frac{d+x}{2}}{\sqrt{\frac{L_s^2}{4} - \left(\frac{d+x}{2}\right)^2}}$$

(b) $l = 35cm$.

Table for ω_{beat}

Sl.No.	T(s)	$\frac{2\pi}{T}$ rad/s
1	25.21	0.2492
2	25.29	0.2484
3	25.19	0.2494
4	25.97	0.2419

$(\omega_{beat})_{2,avg} = 0.2473$ rad/s

$\therefore (\omega_-)_2 = \omega_+ + (\omega_{beat})_2$

$= 4.412$ rad/s

$\therefore (K_{expt})_2 = \frac{m}{148.65 \times 10^{-3}} \left((4.412)^2 - (4.165)^2\right)$

$= 1.287$ rad/s.

(c) $l = 45cm$.

Table for ω_{beat}.

Sl.No.	T(s)	$2\pi/T$ rad/s
1	16.22	0.3874
2	16.59	0.3787
3	16.21	0.3876
4	16.53	0.3801

$(\omega_{beat})_{3,avg} = 0.3835$ rad/s.

$(\omega_-)_3 = \omega_+ + (\omega_{beat})_3$

$= 4.548$ rad/s

$(K_{expt})_3 = \frac{148.65 \times 10^{-3}}{2(0.45)^2} \left((4.548)^2 - (4.165)^2\right)$

$= 1.226$ rad/s.

Topic :

PIONEER

Page :

Date : / /

$F - F' = -Kx + O(x^2)$.

We ignore term involving $O(x^2)$ to be small and we approximate excess force.

$K_{estim} = \frac{mg}{2} \frac{Ls^2}{(Ls^2 - d^2)^{3/2}}$.

where

Ls = Length of string.

m = mass hanging from string

d = horizontal distance b/w the two end of spring.

We now calculate K_{expt} for three different values of l i.e 25cm, 35cm, 45cm.

ERROR ANALYSIS.

(A) Error in Kestim. (Maximum Possible)

$$K_{estim} = \frac{mg}{2} \frac{L_s^2}{(L_s^2 - d^2)^{3/2}}$$

Taking log and differentiating we obtain absolute error.

$$\frac{dK_{est}}{K_{est}} = \frac{dm}{m} + 2\frac{dL_s}{L_s} + 3\left|\frac{dL_s - d(d)}{L_s^2 - d^2}\right|$$

Given, $dL_s = 0.1\,cm$

$\Delta(d) = 0.1\,cm$.

$dm = 1g$.

We find the absolute Error.

$$\frac{d\,K_{est}}{K_{est}} = \frac{dm}{m} + 2\frac{dL_s}{L_s} + \frac{3}{2}\left(2\frac{\Delta L_s}{L_s} + 2\frac{\Delta d}{d}\right)$$

$$= \frac{dm}{m} + 5\frac{dL_s}{L_s} + 3\frac{\Delta d}{d}$$

$$= \frac{1}{24} + 5\times\frac{0.1}{17.7} + 3\times\frac{0.1}{11}$$

$$= 0.0971$$

∴ % Y. Error = 9.71 %. Maximum possible Error in Kestim.

(B) Error in Moment of Inertia.

$$I = M_{bob}L^2\left(1 - \frac{h}{L}\right) + \frac{1}{3}M_{rod}L^2\left(1 - \frac{2h}{L}\right)$$

Taking log within both side.

$$\log I = 4\log L + \log M_{bob} + \log M_{rod} + \log(L-h) + \log(L-2h).$$

differentiating and finding max error,

$$\frac{dI}{I} = \frac{4\,dL}{L} + \frac{dM_{bob}}{M_{bob}} + \frac{dM_{rod}}{M_{rod}} + \frac{(\Delta L + \Delta h)}{|L-h|} + \frac{\Delta L + \Delta h}{|L-2h|}$$

$$\frac{dI}{I} = 4\times\frac{0.1}{85} + \frac{10^{-2}}{170.86} + \frac{10^{-2}}{132.05} + \frac{0.1\times2}{82} + \frac{0.1\times2}{79}.$$

$$\frac{dI}{I} = 0.0098.$$

∴ % Error in I = 0.98 %.

(c) Standard Deviation of K_{expt}.

$(K_{expt})_1 = 1.204$ N/m.

$(K_{expt})_2 = 1.287$ N/m.

$(K_{expt})_3 = 1.226$ N/m.

$\bar{K} = (K_{expt})_{avg} = \dfrac{K_1 + K_2 + K_3}{3}$

$= \dfrac{1.204 + 1.287 + 1.226}{3}$

$= 1.239$ N/m

∴ Standard deviation,

$\sigma = \sqrt{\dfrac{1}{3-1}\left[(1.239 - 1.204)^2 + (1.239 - 1.287)^2 + (1.239 - 1.226)^2\right]}$

$\sigma = \sqrt{\dfrac{1}{N-1}\sum_i^N (\bar{K} - K_i)^2}$

$= 0.043$

∴ % Error $= \dfrac{\sigma}{\bar{K}} \times 100 = 3.47\%$

(d) Relative Error from K_{estim}.

$K_{estim} = 1.318$ N/m.

$(K_{expt})_{avg} = 1.239$ N/m

∴ % Error $= \dfrac{|K_{estim} - K_{expt}|}{K_{estim}} \times 100$

$= \dfrac{1.318 - 1.239}{1.318} \times 100 = 5.988 \approx 6\%$

Topic:

Page:

Date: / /

CONCLUSION:

From the experiment, we determined

$K_{expt} = 1.239 \pm (3.47\%)$ N/m

And calculated, $K_{estim} = 1.318 \pm (9.71\%)$ N/m

And the relative error in K_{expt} from K_{estim} = 6%

The Error in Moment of Inertia = 0.98%

SOURCES OF ERROR (DISCUSSIONS)

(i) When we take the time using stopwatch, there is a chance of human error.

(ii) While we consider the pendulum with no movement, still it might be in little oscillation which affect the reading.

(iii) After few oscillations, the pendulum does not stop properly, (while measurement of beat frequency).

Topic :

PIONEER®

Page :

Date : / /

(iv) The bob on th string is not at middle position all the time, which may affect the reading.

Topic : M3

PIONEER

Page :

Date : 18 / 5 / 2023

AIM

To verify Newton's second Law of Motion, using linear air track.

WORKING FORMULA

Newton's 2nd Law of motion: $F = m'a$.

Where,

F = Applied Force

m' = Total accelerating mass

a = acceleration.

Applied Force, F = Mass of weight hanging on pulley (m) × acceleration due to gravity (g)

$= m \times g = mg$.

Total accelerating mass, m' = Mass of weight hanging on pulley (m) + Total mass of glider including no. of 100 gm weights (M) = $(m + M)$

We can verify 2nd Law of motion by two ways-

(i) By keeping the total accelerating mass as constant and prove that applied force is proportional to acceleration.

Topic :

PIONEER

Page :

Date : / /

(ii) By keeping the applied force constant and prove that acceleration is inversely proportional to the accelerating mass (m')

$F = mg = (M+m)a$. , $g = 9.8\ m/s^2$.

OBSERVATIONS AND CALCULATIONS

(A) Table-1 Determination of acceleration for a given accelerated mass with varying Force.

Sl. No.	m (g)	F (N)	m+M (g)	a (cal.) (m/s²)	a (expt.) (m/s²)
1.	1.37	0.0134	89.96	0.1492	0.1385
2.	2.05	0.0201	89.96	0.2233	0.2076
3.	2.73	0.0268	89.96	0.2974	0.2805
4.	3.37	0.0330	89.96	0.3671	0.3510
5.	4.03	0.0395	89.96	0.4390	0.4160.

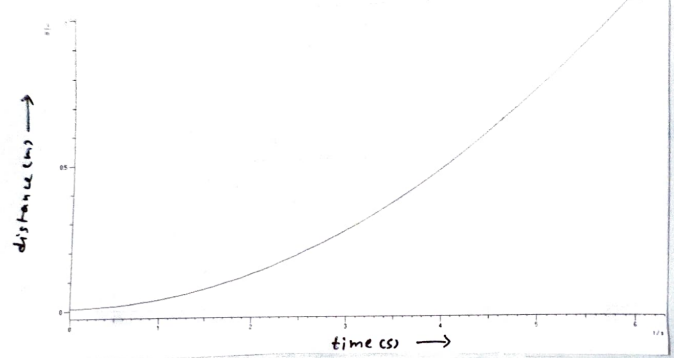
~~F=T=0~~ % Error of measured acceleration, from each reading.

% error = $\frac{(a_{expt} - a_{cal})}{a_{cal}} \times 100\%$.

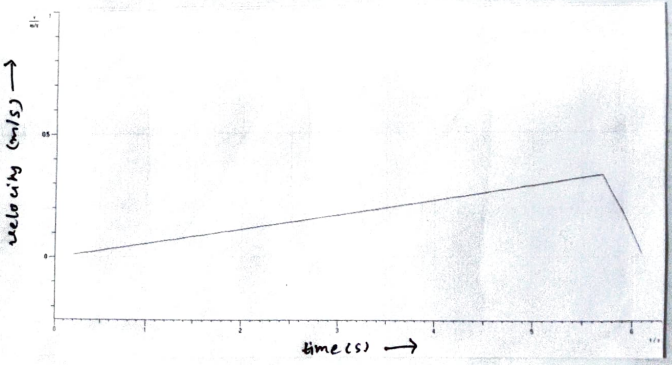
Don't use

1) -7.199%, 2) -7.040%, 3) -5.682%, 4) -4.391%.

5) -5.243%.



(a)



(b)

Topic :

PIONEER

Page :

Date : / /

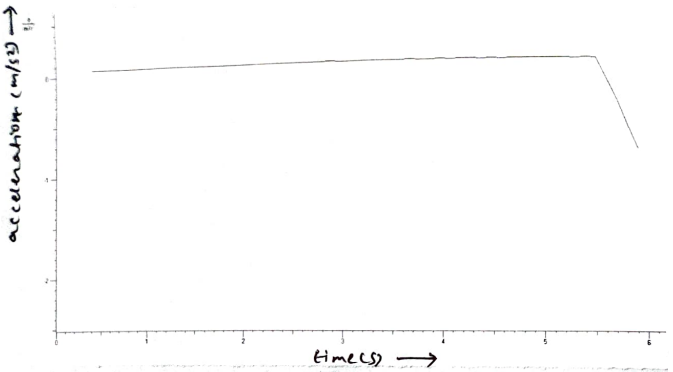
(b) **Table 2** Determination of acceleration for different accelerated mass with a constant force.

Sl.No.	m (g)	F (N)	m+M (g)	a (m/s²) (calc)	a (m/s²) (expt)	1/a (expt) (s²/m)
1	2.05	0.0201	87.98	0.2283	0.2125	4.706
2	2.05	0.0201	187.98	0.1069	0.0965	10.36
3	2.05	0.0201	287.98	0.0698	0.0605	16.53
4	2.05	0.0201	387.98	0.0518	0.0435	22.99
5	2.05	0.0201	487.98	0.0412	0.0350	28.57

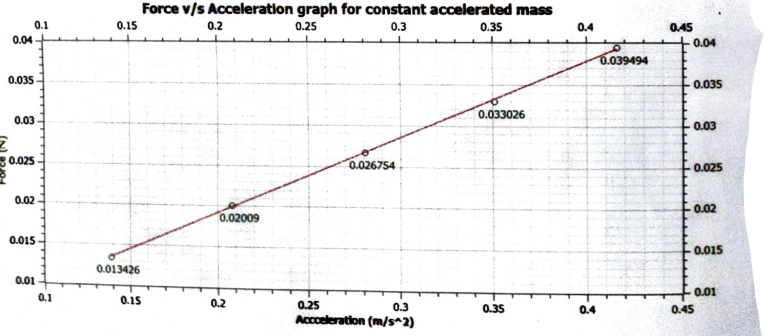
% Error of acceleration in each reading.

1) -6.940 %.
2) -9.706 %.
3) -13.28 %.
4) -15.99 %.
5) -14.99 %.

* Here, we have pasted the graphs of dist. v/s time (a), velocity v/s time (b), acceleration v/s time (c), for the experiment (in Table-1) with m = 3.37g.



(c)



(d)

Topic :

PIONEER

Page :

Date : / /

(c)

Now, we plot the Force (F) v/s acceleration (a) with keeping constant accelerated mass of the system. (Graph-(c)) for the 5 readings in (Table--1).

After linear fitting the plot, we obtain a straight line with,

slope = 0.0931 = m

Intercept = 0.0006

$F = (M+m)a$.

$y = mx$

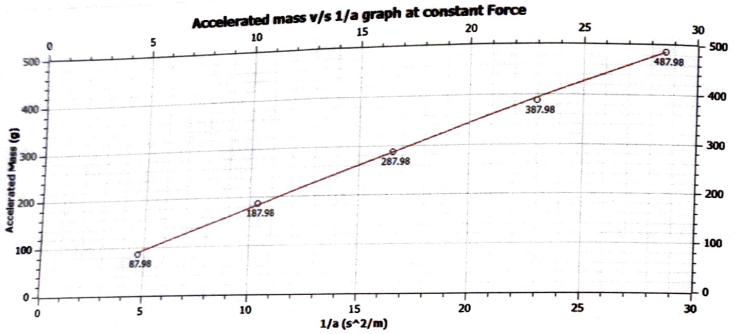
slope is value of (M+m) in kg.

$\therefore$ 0.0931 kg = 93.1 g = (M+m)

(d)

Further we plot, total accelerated Mass (M+m) v/s (acceleration)$^{-1}$ ($1/a$) with keeping constant applied Force. (Graph-(e)).

for the 5 readings in (Table-2).



(e)

slope ?

Topic :

Page :

Date : / /

After linear fitting the plot, we obtain a straight line ~~with~~ with,

Slope - 16.5590 = γ

Intercept - 12.5840

$(M+m)\,a = F$

$(M+m) = F \times \frac{1}{a}$

$y = \gamma \cdot x$

Here, value of slope = $F \times 10^3$

$\therefore (F)_2 = 16.5590 \times 10^{-3}$ N

$= 0.0166$ N

ERROR ANALYSIS.

Error in calculating the

(or) total accelerating mass (from graph(c))

$(M+m)_{theo} = 89.96\,g$

$(M+m)_2 = 93.10\,g$

% Error $= \frac{(93.10 - 89.96)}{89.96} \times 100$

$= 3.49\%$

(b) Error in calculating the ~~tot~~ constant Force (from graph (e)).

$(F)_{theo} = 0.0201\ N$

$(F)_2^e = 0.0166\ N$.

$$\% \text{ Error} = \frac{0.0166 - 0.0201}{0.0201} \times 100$$

$$= -17.41\%$$

?

CONCLUSION

From graph-(d) we found that for a constant accelerating mass,

$F \propto a$, where total accelerating mass is constant $= (93.10 \pm 3.49\%)\ g$

From graph-(e), we found that for a constant applied Force, the accelerating mass is inversely proportional to acceleration.

$(M+m) \propto \frac{1}{a}$, where applied force is constant $= (0.0166 \pm 17.41\%)\ N$

Topic :

Page :

Date : / /

Hence, from the above two observations we conclude that $F \propto (M+m) \times a$ .or $F = (M+m)a$

Hence Newton's second law is verified experimentally with the help of Air track.

SOURCES OF ERROR (DISCUSSIONS)

1) The experimental setup (Air Track) is not ideal, and hence has friction, which has not been considered in our experiment.

(2) Pulley was not frictionless, which was not taken into account in our experiment

(3) The string was also not massless, which contributed to some error.

(4) Air Resistance was also present.

Topic : M 6

PIONEER

Page :

Date : 1 / 6 / 2023

AIM

Precise determination of local gravitational acceleration (g) from the study of small angle oscillation of a reversible pendulum (Kater's pendulum)

WORKING FORMULA.

A time period of a compound pendulum is given by $T = 2\pi \sqrt{\frac{I}{MgL}}$ ①

~~Now~~,

where I = Moment of Inertia.

L = Dist. of pivot from centre of mass.

g = Acceleration due to gravity (to be determined)

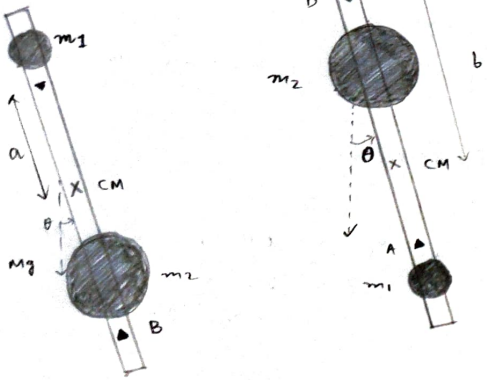
Now,

$I = I_{cm} + Ma^2$. (Parallel Axes Theorem)

$= M(K^2 + a^2)$

M = Total mass of pendulum.

K = being the radius of gyration about the centre of mass.



KATER'S REVERSIBLE PENDULUM

Topic :

Page :

Date : / /

Now,

Time period for small oscillation for the given point A.

$$T_a = 2\pi\sqrt{\frac{I_a}{Mga}} = 2\pi\sqrt{\frac{k^2+a^2}{ga}}$$

and for pivot point B.

$$T_b = 2\pi\sqrt{\frac{I_b}{Mgb}} = 2\pi\sqrt{\frac{k^2+b^2}{gb}}$$

if,

$T_a = T_b$.

$$\Rightarrow \frac{k^2+a^2}{a} = \frac{k^2+b^2}{b}$$

$$bk^2 + a^2b = k^2a + b^2a.$$

$$k^2(b-a) + ab(a-b) = 0$$

$$k^2(b-a) + ab(a-b) = 0$$

$$\rightarrow (k^2-ab)(b-a) = 0$$

either

$$a = b \quad \text{or} \quad ab = k^2.$$

Putting in any eqⁿ (since $a \neq b$)

$$T_a = T_b = T = 2\pi\sqrt{\frac{ab+a^2}{ga}}$$

Table A

x_1 (cm)	x_2 (cm)	10 T_a (s)		10 T_b (s)		T_a^2 (s^2)	T_b^2 (s^2)
		Read 1	Read 2	Read 1	Read 2		
25	15	21.47	21.44	20.37	20.25	4.6032	4.1250
25	20	20.63	20.84	20.25	20	4.2954	4.0502
25	25	20.41	20.55	20.03	19.94	4.1943	~~4~~ 3.9940
25	30	19.94	20.04	19.91	19.81	3.9560	3.9442 / 3.9541
25	35	19.79	19.81	19.89	19.88	3.9204	3.9263
25	40	19.50	19.46	19.85	19.78	3.7947	3.9204
25	45	19.37	19.40	19.8	19.8	3.7578	3.8927
25	50	19.53	19.60	19.71	19.75	3.8279	3.8750
25	55	19.50	19.50	19.69	19.68	3.8025	3.9145
25	60	19.60	19.56	19.85	19.72	3.8338	3.9382
25	65	19.68	19.72	19.84	19.85	3.8809	3.9760
25	70	19.96	19.96	19.94	19.94	3.9840	4.0622
25	75	20.09	20.06	~~19.~~ 20.16	20.15	4.0301	4.0946
25	80	20.50	20.46	20.19	20.28	4.1943	~~4~~
25	85	20.63	20.63	20.41	20.53	4.2560	4.1902
25	90	21.07	21.01	20.78	20.66	4.4268	4.2932

$$\Rightarrow g = \frac{4\pi^2 (a+b)}{T^2} \quad -(1)$$

OBSERVATIONS

For our apparatus.

$d = a+b =$ dist. b/w two knife-edges. (pivot points) and tabulate data.

$d = a+b = 98$ cm.

$m_1 = 1$ kg

$m_2 = 1.4$ kg.

$T_a =$ Time period when oscillated from pivot A.

$T_b =$ Time period when oscillated from pivot B (reverse)

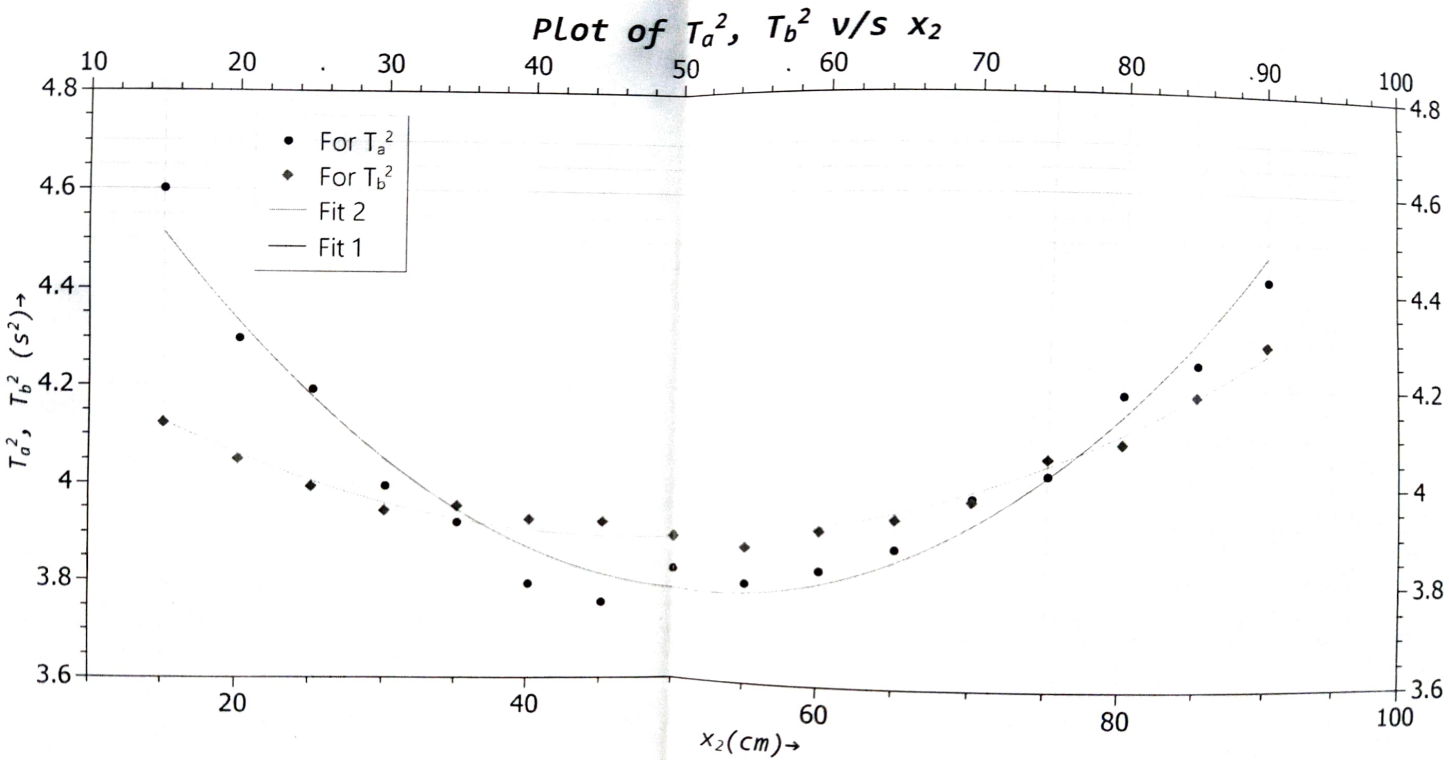
$x_1 =$ distance of m_1 from A.

$x_2 =$ distance of m_2 from A.

~~In each case~~

Here $T_{a/b} = \frac{1}{10}\left\{\frac{(\text{Read 1} + \text{Read 2})}{2}\right\}$

data is tabulated in Table A


Plot of T_a^2, T_b^2 v/s x_2
For T_a^2
For T_b^2
Fit 2
Fit 1
T_a^2, T_b^2 (s^2)→
x_2(cm)→
10
20
30
40
50
60
70
80
90
100
4.8
4.6
4.4
4.2
4
3.8
3.6

Topic :

PIONEER

Page :

Date : / /

CALCULATIONS

Now we plot (on the same graph) T_a^2 and T_b^2 as a function of x_2.

Then we fit the data by a second order polynomial.

The fitted curves are →

T_a^2 v/s x_2 : (Fit 1)

$y = a_2 x^2 + a_1 x + a_0$

$a_2 = 5.0723 \times 10^{-4}$

$a_1 = -5.3795 \times 10^{-2}$

$a_0 = 5.2069$

T_b^2 v/s x_2 : (Fit 2.

$y = b_2 x^2 + b_1 x + b_0$.

$b_2 = 2.1816 \times 10^{-4}$

$b_1 = -2.0933 \times 10^{-2}$

$b_0 = 4.3915$

We obtain two intersection points when we set $T_a = T_b$, namely T_1^2 & T_2^2

~~For~~ .

At

$x_1 = 36.603$ cm, $T_1^2 = 3.9174$

$x_2 = 77.050$ cm, $T_2^2 = 4.0734$.

The average value ~~of~~, ~~for~~ then

$$T^2 = \frac{T_1^2 + T_2^2}{2} = \frac{3.9174 + 4.0734}{2}$$

$$= 3.9954.$$

~~For~~ Putting in eq ①

$$(g)_{exp} = \frac{4\pi^2 (a+b)}{T^2}.$$

$$= \frac{4 \times \pi^2 \ 0.98}{(3.9954)^2} = 9.6834 \ m/s^2$$

ERROR ANALYSIS

The true value g, (as measured at Kolkata) is $g_0 = 9.7882 \ m/s^2$

$$\therefore \text{Error } \% = \frac{g_{exp} - g_0}{g_0} \times 100 = \left| \frac{9.6834 - 9.7882}{9.6834} \right| \times 100$$

$$\simeq -1.07 \ \%.$$

Error = $|g_{observed} - g_{true\ value}|$

As it is taken $g_{true\ value}$ in modulus, there is no negative sign.

Topic :

PIONEER

Page :

Date : / /

CONCLUSION

From our experiment, we determined the value of acceleration due to gravity, $g = 9.6834\ m/s^2$, with an error of $\pm 1.07\%$.

SOURCES OF ERROR (DISCUSSION).

1) ~~Readi~~ Actual Reading might differ, due to slow reflex Meaning ?

2) The oscillation of the Kraten's pendulum, might not be in the same plane.

3) ~~There~~ For some ~~oscillations~~ readings, a large angle of oscillation might have been present.

4) Pivot Points may not be perfectly stable.