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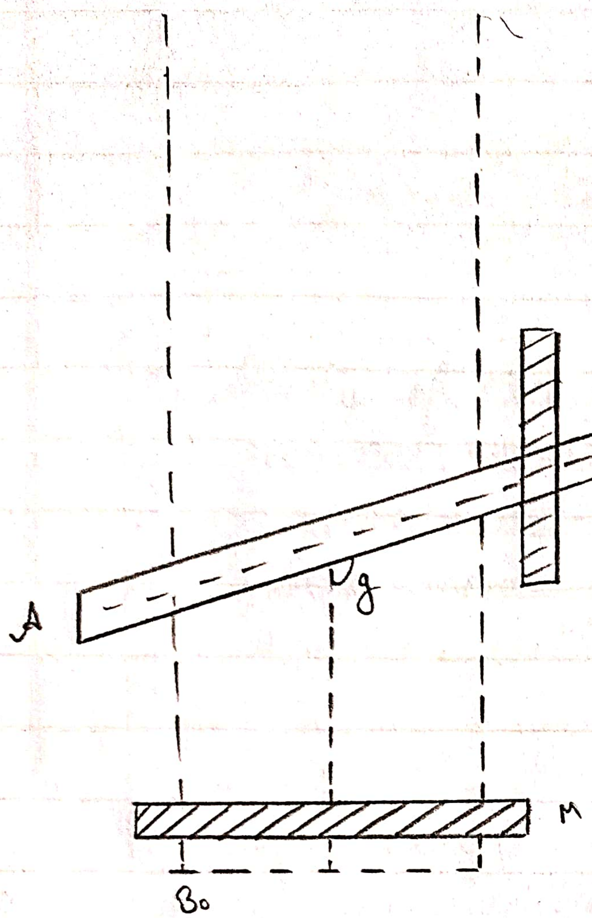

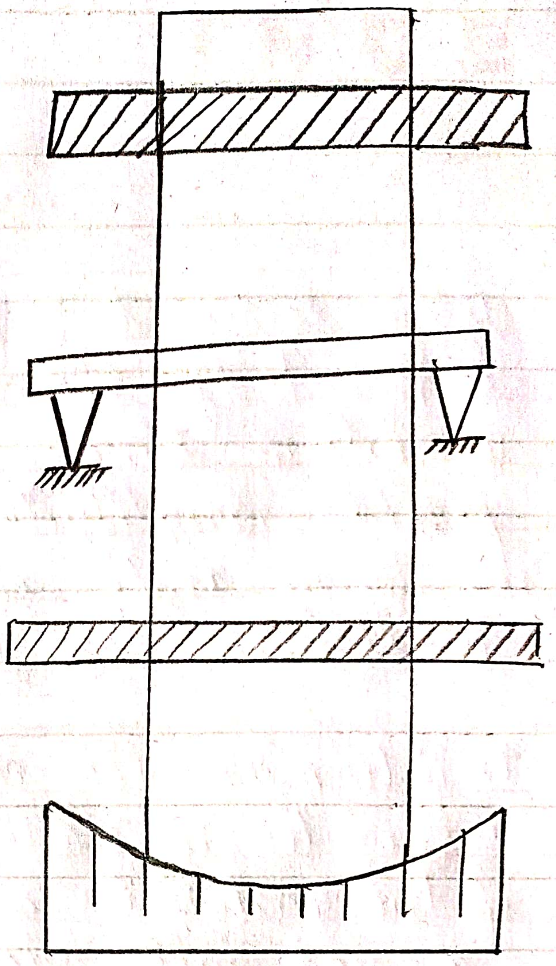

Rigid Pendulum for study of large angle oscillation

Experiment - 1

Objective :-

Using compound pendulum, study the variation time peroid amplitude in large angle of oscillation.

Apparatus Required :-

Compound pendulum, stopwatch large scale measuring the angular displacement.

Theory :-

Compound pendulum, time period is given by

$$\text{Time period} = \frac{\text{time of oscillation}}{\text{Oscillation}}$$

Observation Table :-

S.NO	Oscillation	Time for oscillation	Time
1.	5	4 sec	0.8 sec
2.	10	6 sec	6 sec
3	15	10 sec	67 sec
4	20	12 sec	6 sec
5.	25	15 sec	6 sec

Result :-

The time decreases when we increases oscillation of compound pendulum. Therefore, curve is non-linear.

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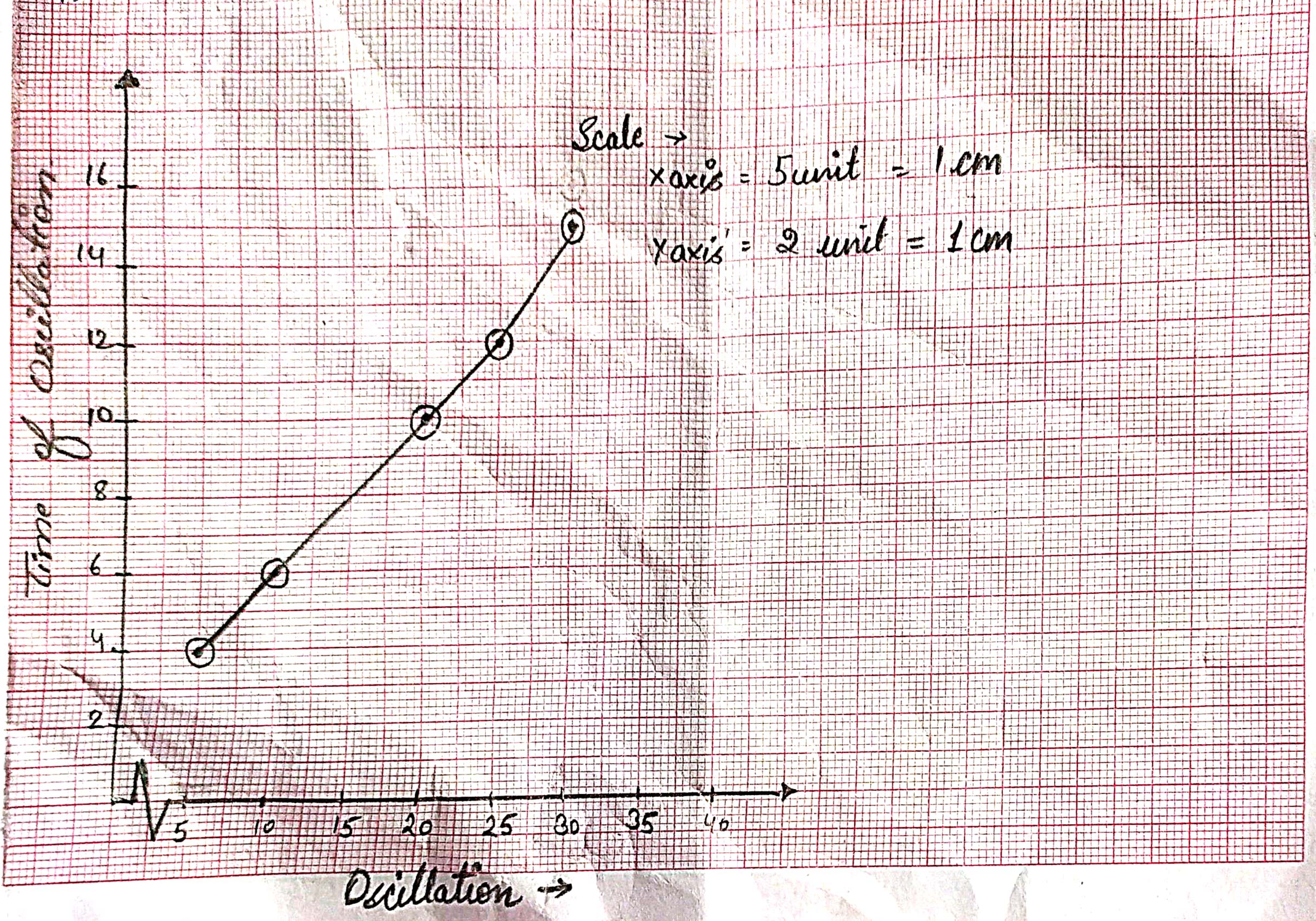
Scale →
x axis = 5 unit = 1 cm
y axis = 2 unit = 1 cm
Time of Oscillation
16
14
12
10
8
6
4
2
5
10
15
20
25
30
35
40
Oscillation →

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Precaution ÷

Pointer should not touch the scale during the oscillation.

Source of error ÷

1. If knife edge of the pendulum is not sharp demping will be more.

2. If electronic time not available the time period for a particular amplitude can not be accurately determine

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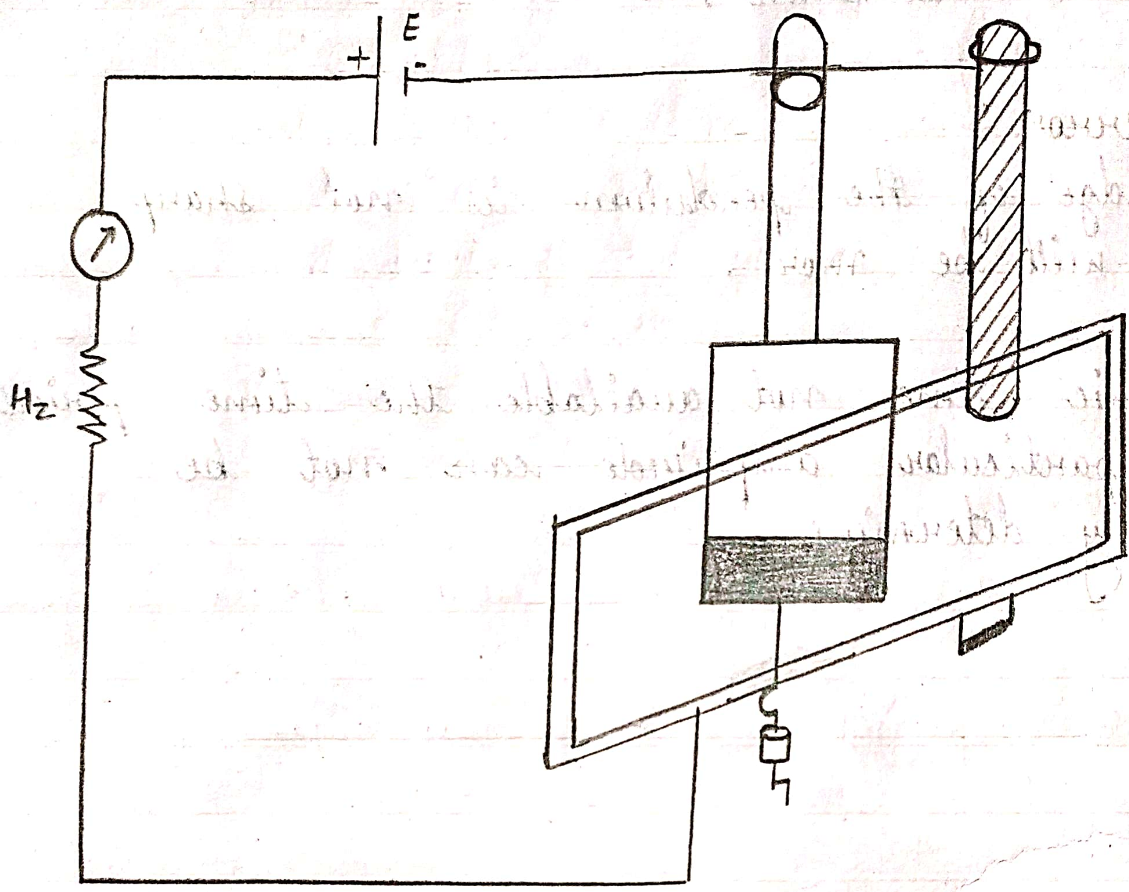


fig ÷ Apparatus for determining the young 's' modulus of root by bending of beam.

Experiment = 2

Objective : To determine the young's modules of elasticity of the matareal of a road with rectangular cross-section of bonding of beam.

Apparatus :

A rod with a rectangular cross section, two knife edges fixed on a rigid support, weight, hanger, plug key, spherometer, meter scale, screw guage, high resistance, galuanometer etc.

Theory :

$$Y = \frac{Mgl^3}{4Sbd^3}$$

Y = young modulus of elasticity

M = Supended weight in kg

g = $9.8\ m/s^2$

l = length of the rod between two knife edge in meter.

b = breadth of rod in meters.

d = thickness of the rod in meters.

S = depression of the rod in meters due to suspended mass ms.

Observation :

Distance b/w two knife edge $l = 0.98$, for determining the breadth of the rod, one division of main scale of vernier $n = 10$

Least count of vernier callipers $\frac{x}{m} = 0.01\ cm$

Calculation →

$$Y = \frac{mgl^3}{4Sbd^3}$$

$m \Rightarrow 2\,kg$ $\quad g \Rightarrow 9.8\,m/s^2$

$l \Rightarrow 98\,cm \Rightarrow 0.98\,m$

$b \Rightarrow 2\,cm \Rightarrow 0.02\,m$

$d \Rightarrow 0.62\,cm \rightarrow 0.0062\,m$

$S \Rightarrow 0.00256\,cm$

$$Y = \frac{2 \times 9.8 \times (0.98)^3}{4 \times 0.00256 \times 0.02 \times (0.0062)^3}$$

$$Y = \frac{18.447}{4.88}$$

$$Y = 3.780 \times 10^{11}\ N/m^2$$

Observation table ÷

S.No	Main Scale	Vernier calliper Reading — Vernier Scale	Total	Mean (b) (Cm)
1.	3.7	8 X 0.01 = 0.008	3.78	
2.	3.7	7 X 0.01 = 0.007	3.78	3.78
3.	3.7	9 X 0.01 = 0.009	3.79	

→ for determining the depressions.

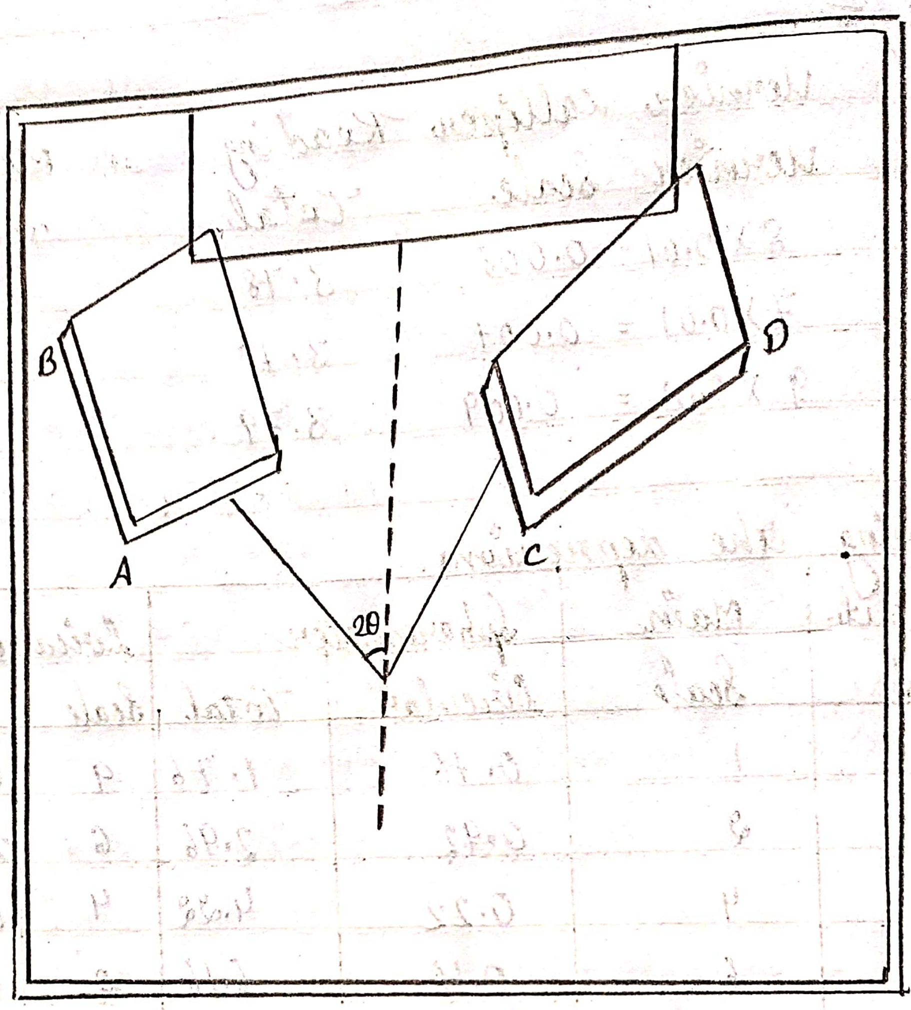
S.No	Additional wt. Suspended	Main Scale	Spherometer Circular	Total	Circular Scale	main micro scope	depres sion	Sea te
1.	0	1	0.76	1.76	9	0.52	9.52	
2.	1/2	2	0.92	2.96	6	0.51	6.51	12.3
3.	1	4	0.22	4.22	4	0.84	4.84	
4.	3/2	6	0.16	6.16	2	0.12	2.12	
5.	2	9	0.52	0.52	1	0.70	1.70	

Result ÷ Young 's modules of the rod
$Y = 3.780 \times 10^{11}\ N/m^2$

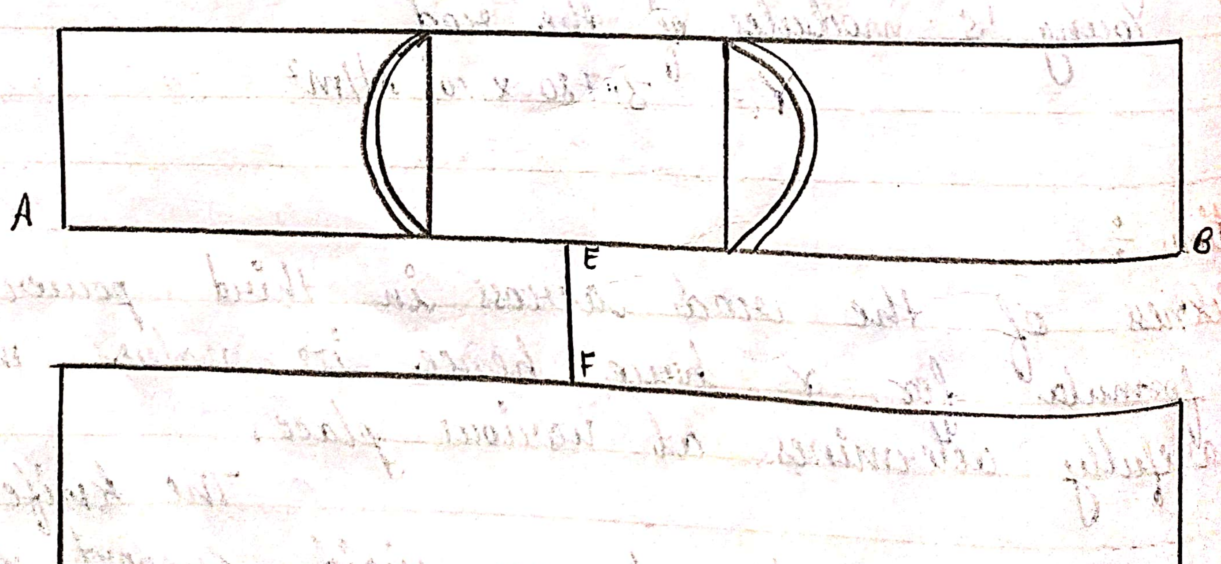
Precaution ÷

The thickness of the rod across in third power in the formula for Y have hence its values must be carefully determines at various place.

The knife edges must be tightly clamped on rigid support and these must be equidistant from spherometer screw.



(Bending Oscillation)



[Torisonal Oscillation]

Experiment = 3

Object :- To determine young's modulus of rigidity and poision is ratio of a given wire by searl's apparatus.

Apparatus Required :- Searl's apparatus, stop watch, screw guage, vernier callipers, thread, meter scale, physical balance, weight box, candle, match box etc.

Theory :-

$$Y = \frac{8\pi l I}{T_1^2 r^4}$$

$$n = \frac{8\pi l I}{T_2^2 r^4}$$

$$\sigma = \frac{T_2^2}{2T_1^2} \quad \text{——— (1)}$$

Where :-

l = length of experimental wire.
r = radius of experimental wire.
T_1 = Timeperoid of bending oscillation.
T_2 = Time peroid of torisonal oscillation.

$$I = M\left[\frac{L^2 + B^2}{12}\right]$$

Observation :-
Length of the experimental wire $l = 0.3m$ for the measurement of radius (r) of a wire, one direction of a main scale of S.G.n $= \frac{0.001m}{10}$ +

for the measurement of breadth, diameter of rods

Calculation :-

(i) $I = m\left(\frac{L^2 + B^2}{L^2}\right)$

$m = 0.2544\ kg$

$l = 0.3m$

$b = 0.0119\ cm$

$I = 0.2544 \left[\frac{(0.3)^2 + (0.0119)^2}{12}\right]$

$I = 0.212\ [0.09 + 0.00014161]$

$I = 0.212 \times 0.09014161$

$I = 0.0019110$

$I = 1.911 \times 10^{-3}\ kg/m^3$

(ii) $V = \frac{8\pi l I}{T_1^2 r^4} = \frac{8.314 \times 0.31 \times 1.911 \times 10^{-3}}{(21.6)^2 \times (9.658 \times 10^{-4})^4}$

$32.91 \times 10^8\ N/m^2$

(iii) $\eta = \frac{8\pi l I}{T_2^2 r^4} = \frac{8 \times 3.14 \times 0.3 \times 1.911 \times 10^{-3}}{(35)^2 \times (9.658 \times 10^{-4})}$

$= 12.53 \times 10^8$

are division of a main scale.

V.C = 0.001 , no. of vernier division n = 10

least count of a V.C = $\frac{x}{n}$ = $\frac{0.001}{10}$

Observation Table :-

S.No.	M.S Reading	V.S Reading	Total reading	Mean (2r)	Mean(r)
1.	0.001	0.00095	0.00195		
2.	0.001	0.00092	0.00192	0.001926	9.635
3.	0.001	0.00091	0.00191		

S.No.	MS Reading	V.S Reading	Total reading	Mean (b)
1.	0.011m	0.001	0.012 m	0.0119 m
2.	0.011m	0.008	0.118 m	

m = 0.2594 kg

l = 0.3m

for measurement of T_1 & T_2

S.No	No. of oscillation	for time (T_1)	Mean	for time (T_2)	Mean
1.	5	6		10	
2.	10	12		20	
3.	15	19	21.6	30	35
4.	20	25		40	
5.	25	31		50	
6.	30	37		60	

(iv) $6 = \frac{T_2^2}{2\pi^2} - 1$

$\Rightarrow \frac{(35)^2}{2(21.6)^2} - 1$

$\Rightarrow 0.3128$

Result :

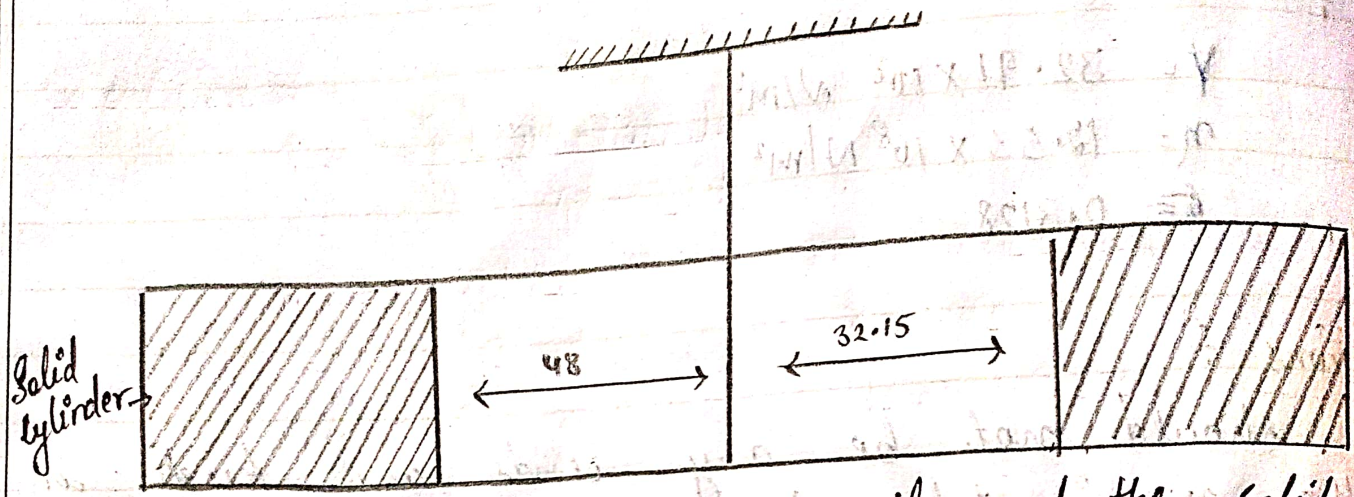
$Y = 32.91 \times 10^8 \ N/m^2$

$\eta = 12.53 \times 10^8 \ N/m^2$

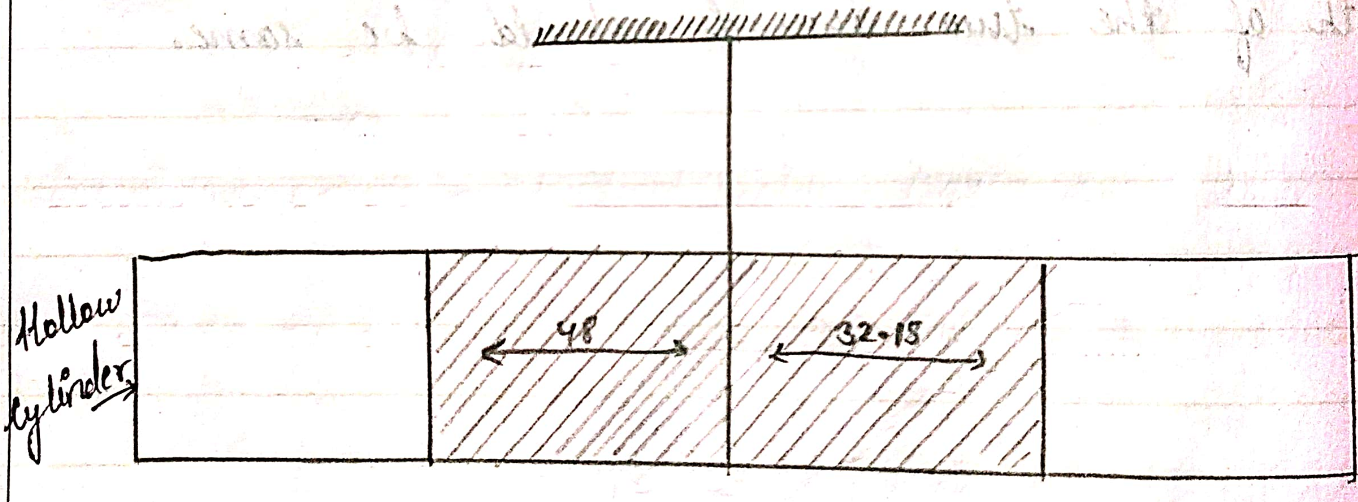
$\sigma = 0.3128$

Precautions :

1. There should not be any bends and kinks in the experimental wire.
2. The bars should be identical and equal moment of ~~~~ inertia.
3. Length of the two threads should be same.



Hollow cylinder are on the inner sides and the solid cylinder are on the outer side



Hollow cylinder are on the outer side and solid cylinder are on the inner side

Experiment - 4

Object : To determine the modulus of rigidity of a wire with the help of maxwell's needle.

Apparatus Required → Maxwell needle, stop watch, metre scale, guage, physical balance, weight box etc.

Theory :

$$n = \frac{8 \times l (m_s - m_n) L^2}{r^4 \cdot T_1^2 - T_2^2}$$

Where, n = modulus of rigidity of the experimental wire.
l = length of the suspension wire in metres.
r = radius of experimental wire in meters.
m_s = mass of solid cylinder in kg.
m_n = mass of hollow cylinder in kg.
T_1 = Time period when the two solid cylinder are on outer side the hollow cylinders are on the inner side inside the maxwell needle.
T_2 = Time period when the two hollow cylinders are on outer side and the solid cylinders are on the inner side inside the maxwell needle.

Observation :

Length of maxwell needle L = 0.3 metre
mass of hollow cylinder m_n = 0.18 kg
mass of solid cylinder m_s = 0.23 kg
Length of experimental wire l = 0.3 metre
measurement of radius of experimental wire value of one division of main scale of screw guage = n = 5cm.

Calculation ÷

$$\eta = \frac{2\times l\,(m_s - m_n)\,L^2}{r^4\,[T_1^2 - T_2^2]}$$

$m_n = 0.1\ kg$ $\quad m_s = 0.23\ kg$

$l = 0.3\ m$ $\quad r = 78\times10^{-5}\ m$

$L = 0.3\ m$ $\quad T_2 = 1.9\ sec.$

$T_1 = 2.5\ sec.$

$$\eta = \frac{2\times3.14\times0.3\,(0.23-0.1)\,(0.3)^2}{(78\times10^{-5}]^4\,[(0.5)^2-(1.9)^2]}$$

$$\eta = \frac{1.884\times0.13\times0.09}{(78)^4\times10^{-20}\,(6.25-3.61)}$$

$\eta = 0.0220428\times10^{20}$

$\eta = 23\times10^{10}$

$$\text{percentage error} = \frac{\text{Standard value} - \text{experimental value}}{\text{Standard value}}\times100$$

$$3.4\times10^{11} - 2.3\times10^{11} = \frac{8.22\times10^{10} - 23\times10^{10}}{8.22\times10^{10}}\times100$$

$$= \frac{5.92\times10^{10}}{8.22\times10^{10}}\times100$$

$= 72.19\ \%$

$$= \frac{3.4\times10^{11} - 2.3\times10^{11}}{3.4\times10^{4}}\times100$$

$$= \frac{1.1\times10^{11}}{3.4\times10^{11}}\times100$$

$$= \frac{1100}{34} \Rightarrow 32.35\%$$

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No. of division on scalar scale = n = 100.
least amount of screw guage $\frac{x}{n} = \frac{5}{100} = \frac{1}{20}$

S.NO	Main scale Reading (cm)	Circular scale Reading (cm)	Total Reading (cm)	mean (2r) cm	mean (r) (cm)
1.	0.1	54	0.154		
2.	0.1	57	0.157	0.156	0.078.
3.	0.1	57	0.157		

→ To determine the periods T_1 and T_2

S.NO	No. of Oscillation	with the solid cylinder of the end				with the hollow cylind-ers at the			
		1	2	mean time	T_1(s)	1	2	mean time	T_2(s)
1.	10	24	76	25	2.5	14	18	18.5	1.8
2.	20	50	52	51	2.5	38	38	38	1.9
3.	30	76	78	77	2.5	57	57	61	1.9

mean T_1 = 5.83 mean T_2 = 4.33

Result :-

η of the experimental wire = 2.3×10^{11} N/cm^2
Standard value of η for steel = 3.4×10^{11} N/m^2
Percentage error :-

Sources of error :-
1. The radius of the experimental wire may not be some through out.
2. These may be kinds in the experimental wire.

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3. The oscillation of the maxwell needle may be not perfectly in the horizontal plane.
4. The oscillation of the needle may be within elastic limits.
5. The maxwell needle may be perfectly horizontal.

Precautions :-
1. The experimental wire must be long and free from kinks.
2. The maxwell needle must be perfectly horizontal.
3. The radius of the wire occurs in fourth power in the formula. Hence it should be carefully measured at various plances.
4. The oscillation of the needle must be perfectly torison -al and there should not be up and down and to and free motion of the needle.
5. The amplitudes of oscillation of the needle must be small otherwise the torisonal oscillations will not be within elastic limit.
6. The time period T_1 and T_2 occur in second power in the formula hence then it should be determined with the help of a sensitive stop watch for larger number of osillation

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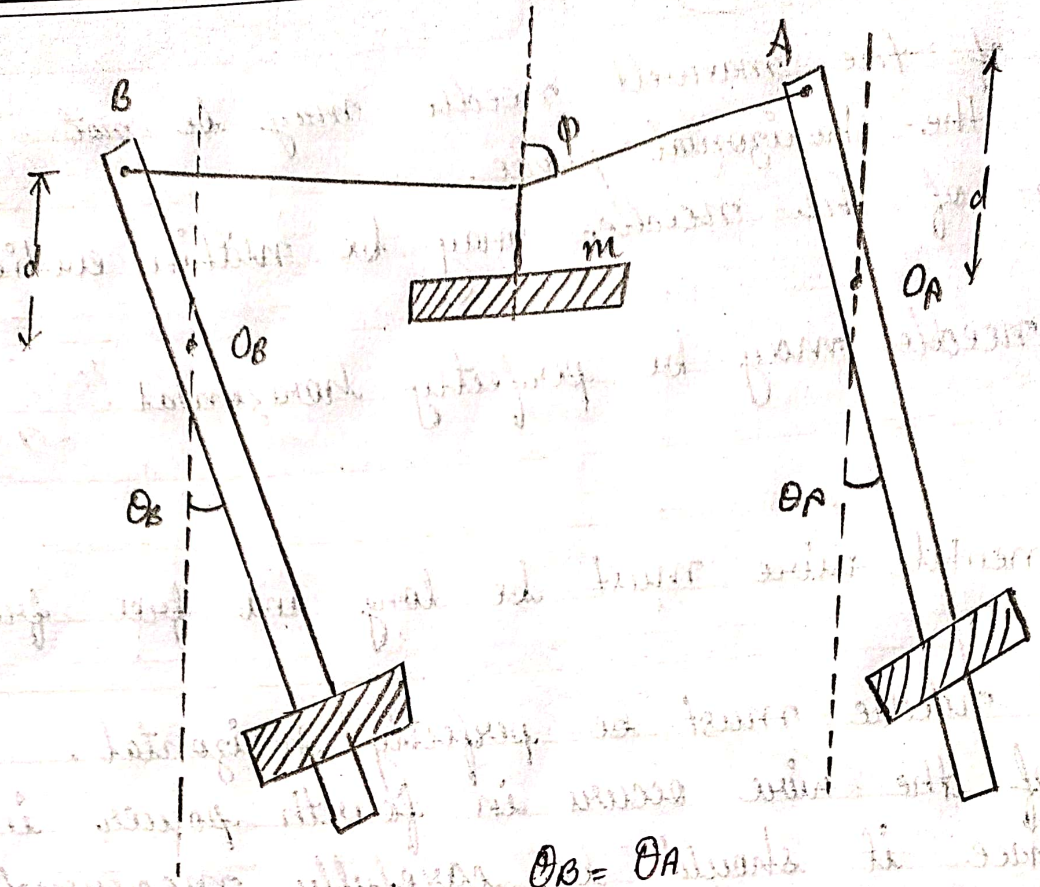

$\theta_B = \theta_A$

fig (1) = first Normal Mode of Vibrations.

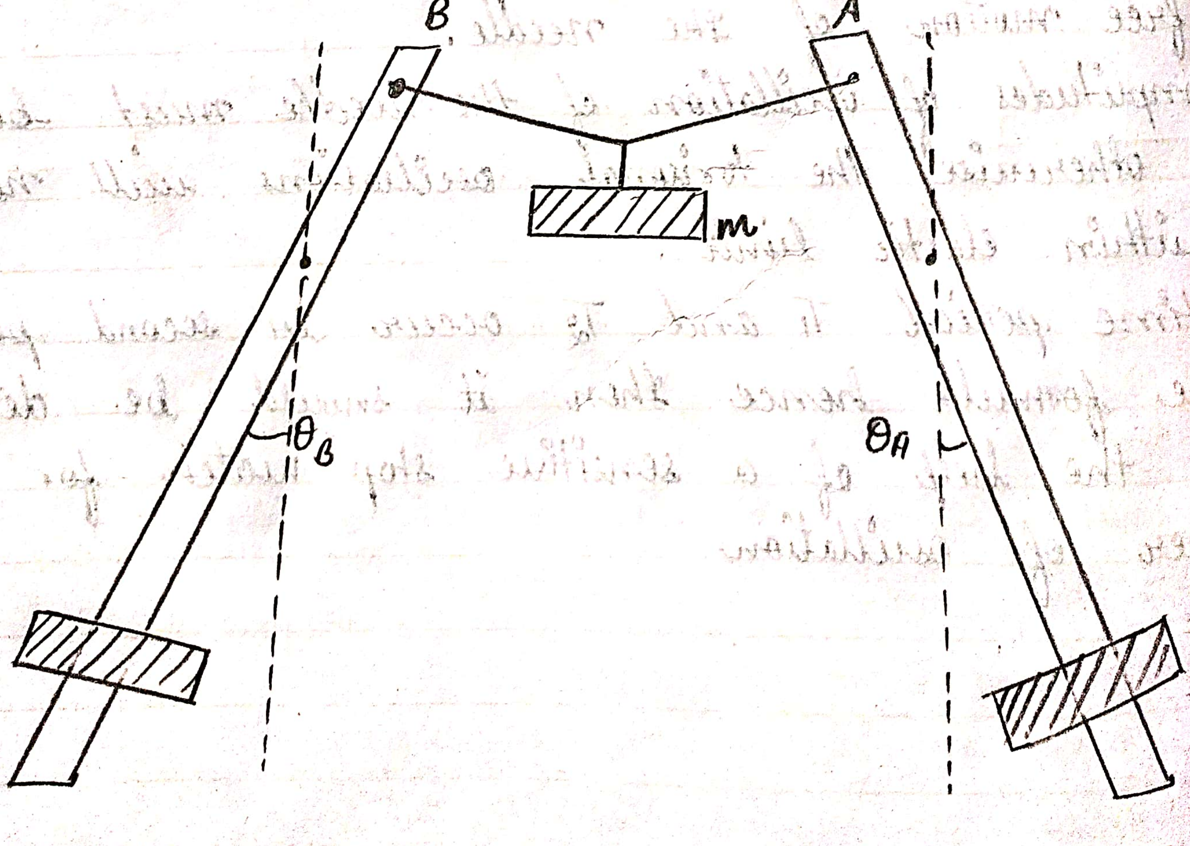

fig (2) Second Normal Mode of Vibrations

Experiment = 5

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Object :-

Study of excitation of normal modes and frequency splitting measurements using coupled oscillator.

Apparatus :-

for performing this experiment New Tech type SETUP - 1026 has been designed fig 2. The setup consists of coupled compound pendulums, a set of slotted weights with hanger, a digital stop clock. The setup is complete. No other accessory is required to perform the experiment.

Theory

On coupling two compound pendulums A and B of same moment of inertia and same periodic time, for first normal mode of vibration fig (1)

$$\theta_A = \theta_B \quad \text{—} (1)$$

Angular frequency in the first normal mode of vibration is given by :-

$$\omega_1 = \sqrt{\frac{C}{I}} \quad \text{—} (2)$$

Where

θ_A = Angular displacement of compound pendulum A.

θ_B = Angular displacement of compound pendulum B.

C = Restoring Torque of each pendulum.

I = Moment of Inertia of each Pendulum.

for second normal mode of vibrations fig (2)

$$Q_A = -Q_B \quad \text{——} ③$$

And the angular frequency in this mode of vibration is given by :-

$$\omega_2 \simeq \omega_1 \left(1 + \frac{C_{AB}}{C}\right) \quad \text{——} ④$$

where coupling constant $C_{AB} = \frac{mgd^2}{2l\cos^3\varphi}$ —— ⑤

frequency difference of two normal modes of vibrat-tions -

$$(\nu_2 - \nu_1) = \frac{\omega_2 - \omega_1}{2\pi} = \frac{C_{AB}\,\nu_1}{C} \quad \text{——} ⑥$$

d, l, φ and C are constants

$$\therefore \boxed{\Delta\nu = (\nu_2 - \nu_1) \propto m} \quad \text{——} ⑦$$

Therefore difference in the frequencies of two normal modes of vibrations is directly proportional to the coupling mass.

Observation Table

S. No.	Coupling mass m gm	First Normal Mode $Q_A = Q_B$				Second Normal mode $Q_A = -Q_B$			
		No. of Oscillat-ions	Time t_1 sec.	Period time $T_1 = \frac{t_1}{n}$	Average Periodic time T_1 sec.	No. of Oscillations	Time t_2 sec.	Period time $t_2 = \frac{t_2}{n}$	Average periodic time t_2 sec
1.	0	(1) 10 (2) 20 (3) 30	15.44 31.22	1.54 1.56	1.57	(1) 10 (2) 20 (3) 30	12.87 26.61	1.2 1.3	1.321
2.	10gm	10 20	15.28 31.48	1.52 1.57	1.54	10 20	12.71 26.79	1.2 1.3	1.315
3.	20gm	10 20	15.64 31.75	1.56 1.58	1.57	10 20	12.78 26.50	1.2 1.3	1.314

Calculations table :-

S. No.	Coupling mass m g.	Frequency of I Normal mode $\nu_1 = \frac{1}{T_1}$ Hz	Frequency of II Normal mode $\nu_2 = \frac{1}{T_2}$ Hz	Frequency diff. $\Delta\nu = (\nu_2 - \nu_1)$ Hz
1.	0			
2.	10	$1/1.57 = 0.63$	$1/1.321 = 0.757$	0.127
3.	20	$1/1.54 = 0.64$	$1/1.315 = 0.760$	0.12
4.	30	$1/1.57 = 0.63$	$1/1.314 = 0.761$	0.131

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Result

(1) from the graph between ν_1, ν_2 and m it is clear that the frequency of first normal mode of vibration does not depend on the coupling mass while the frequency of second normal mode of vibrations depends on coupling mass m. It increases with increase in coupling mass.

(2) from the graph between $\Delta\nu$ and m it is clear that difference in frequencies of first and second normal mode of vibrations $(\nu_2 - \nu_1) = \Delta\nu$ is directly proportional to the coupling mass.

Precautions :

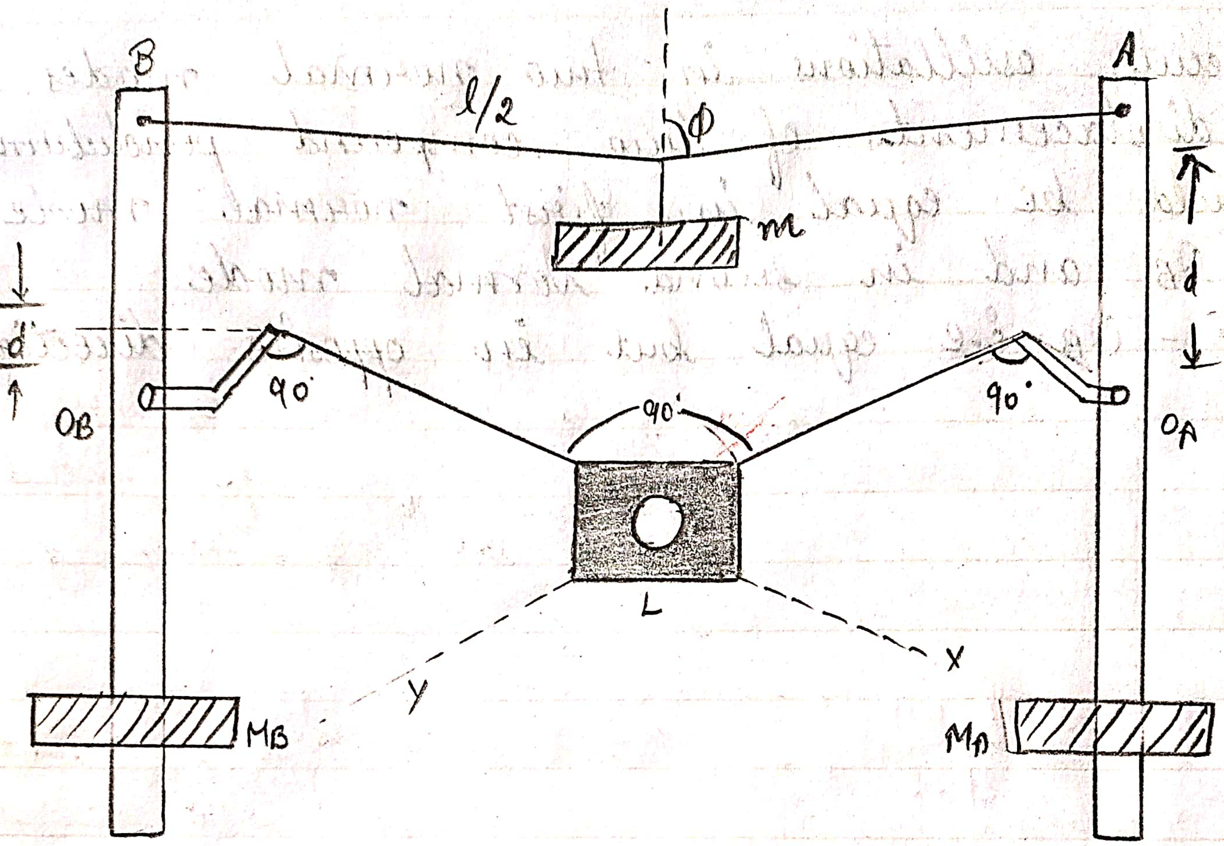
1. Time periods of two compound pendulums should be equal.

2. The knife edges of two compound pendulum should be horizontal.

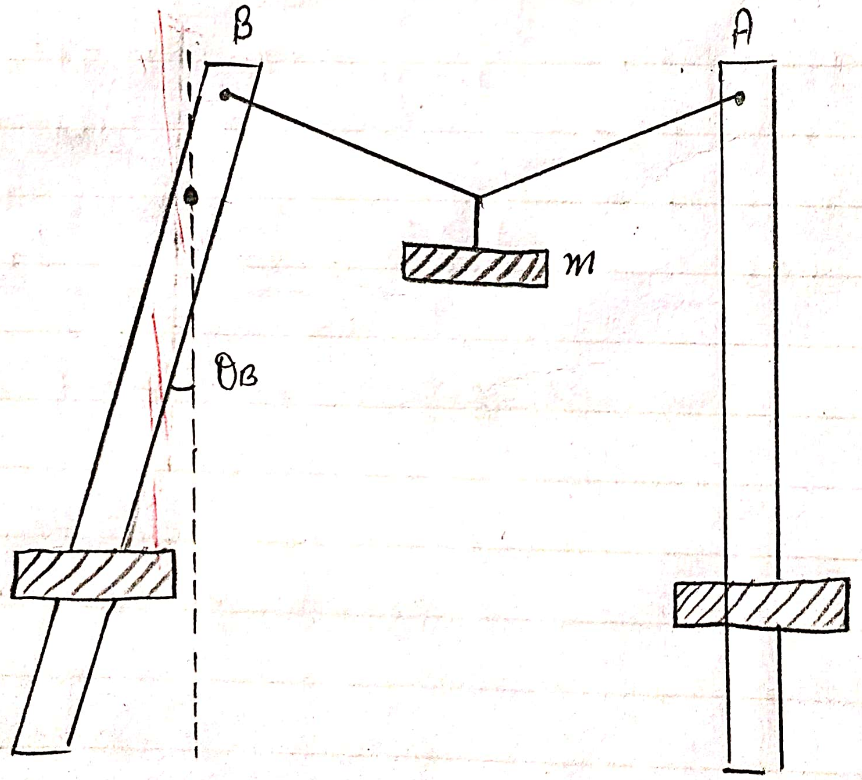
3. knife edges should be sharp

4. The amplitude of Oscillations should be small

5. To execute oscillations in two normal modes the displacements of two compound pendulums should be equal in first normal mode $\theta_A = \theta_B$ and in second normal mode $\theta_A = -\theta_B$ i.e equal but in opposite direction.



B
A
l/2
ϕ
m
d
d'
90°
90°
90°
O_B
O_A
L
X
Y
M_B
M_A



B
A
m
θ_B

Experiment = 6

Object ÷

Study of frequency of energy transfer as a function of coupling strength using coupled oscillators.

Apparatus ÷

for performing this experiment New Tech Type NTI SETUP - 1027 has been designed fig. The setup consists of coupled compound pendulums, a set of slotted weights with hanger, a source of light fixed on a stand, convex lens and a transparent plate on which a graph paper is fixed. The plate is fixed on a vertical stand and a digital stop clock. The setup is complete. No other access-ory is required to perform the experiment.

Theory ÷

Two compound pendulums A and B of equal moment of inertia and equal periodic time are coupled together. Keeping A compound pendulum at rest compound pendulum B is displaced through angle θ_B in outward direction and it is left free. fig (1). The coupled oscillator starts oscillating in mixed mode of vibrations. In this state transfer of energy takes places from B to A compound pendulum. when total energy of B compound pendulum is transferred to compound pendulum A. afterwards energy is transferred A to B compound pendulum. If there is no loss of energy this process will continue. The frequency of this energy transfer B → A → B is given by relation -

$$\Delta \nu = \nu_2 - \nu_1$$

where $\Delta \nu$ = frequency of energy transfer

ν_1 = frequency in I mode of vibration ($\theta_A = \theta_B$)

ν_2 = frequency in II mode of vibration ($\theta_A = -\theta_B$)

$$\nu_2 = \nu_1 \left(1 + \frac{C_{AB}}{C}\right)$$

Where :-

C = Restoring Torque of each pendulum

where coupling constant $C_{AB} = \dfrac{mgd^2}{2l\cos^3\psi}$

m = coupling mass

g = Acceleration due to gravity.

d = distance of thread for coupling mass tied to pendulum from point of suspension.

l = length of coupling thread.

ψ = Angle of inclination of coupling thread.

d, l, ψ and C are constants.

$\therefore \boxed{\Delta V = (V_2 - V_1) \propto M}$

Thus frequency of energy transfer is directly proportional to coupling mass (m).

Observations

Distance between center of suspension of compound pendulum and thread point

d = ______ cm

S.NO.	Coupling mass m gm	No. of times for momentary rest of compound pendulum (n)	Time (t) taken in energy transfer cycles (n) t sec	Periodic time for energy transfer $T = t/n$ (sec)	Average periodic time for energy transfer $\bar{T}$ (sec)	frequency of energy transfer $\Delta V = \frac{1}{T}$ (Hz)
1.	10	(i) 10	20	2	2	0.5
		(ii) 20	40	2		
		(iii) 30	60	2		
2.	20	(i) 10	28	2.8	2.8	0.357
		(ii) 20	56	2.8		
		(iii) 30	84	2.8		

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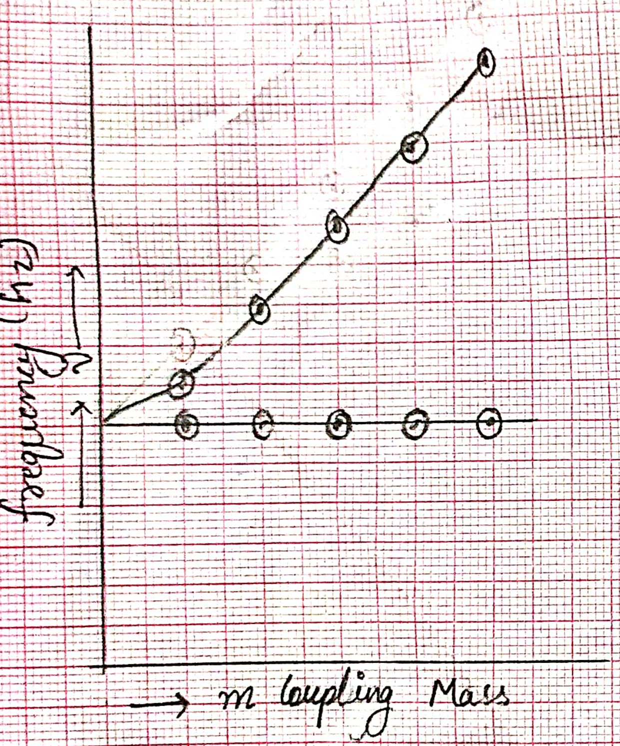

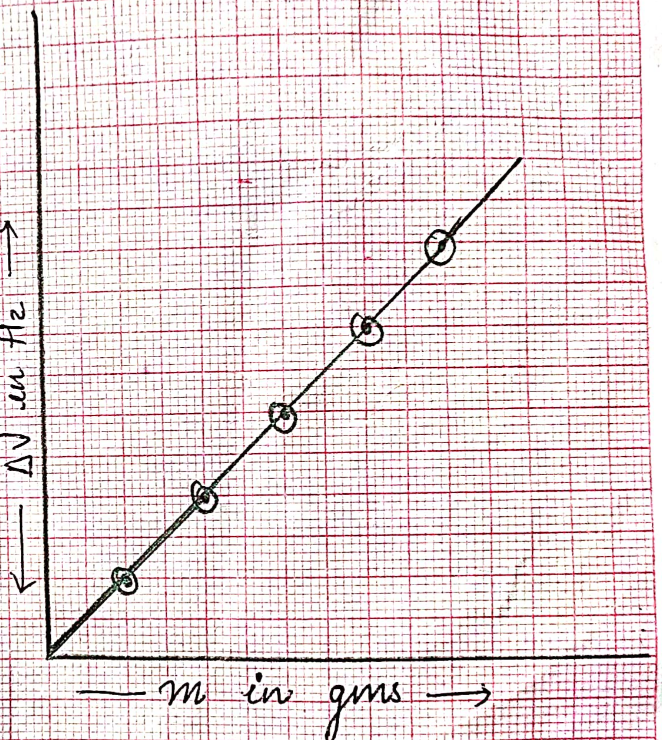

Calculations :

Time period for energy transfer $T = t/n$ (sec).

frequency of energy transfer $\Delta V = \frac{1}{T}$ (Hz).

A graph is plotted between coupling mass (m) and frequency of energy transfer is a straight line. This shows that frequency of energy transfer is directly proportional to coupling mass.

Result :

Graph plotted between coupling mass and frequency of energy transfer is a straight line. This shows that frequency of energy transfer is a straight directly proportional to coupling mass.

Precautions :

1. Time periods of two compound pendulums should be equal.

2. The knife edges of two compound pendulums should be horizontal

3. knife edges should be sharp.
4. The amplitude of oscillations should be small.