||JAI SRI GURUDEV||

**BGS SCIENCE ACADEMY**

Agalagurki, Chickballapur – 562 101

# LABORATORY MANUAL

## B.Sc. PHYSICS

### For II – SEMESTER

### Paper -202


**PREPARED BY TEAM OF PHYSICS DEPARTMENT**

**Mr.SRINIVASA MURTHY P R**
**HOD & ASSISTANT PROFESSOR**

**Ms.LAVANYA S V**
**ASSISTANT PROFESSOR**

**Ms.NAGALAKSHMI L**
**LAB INSTRUCTOR**

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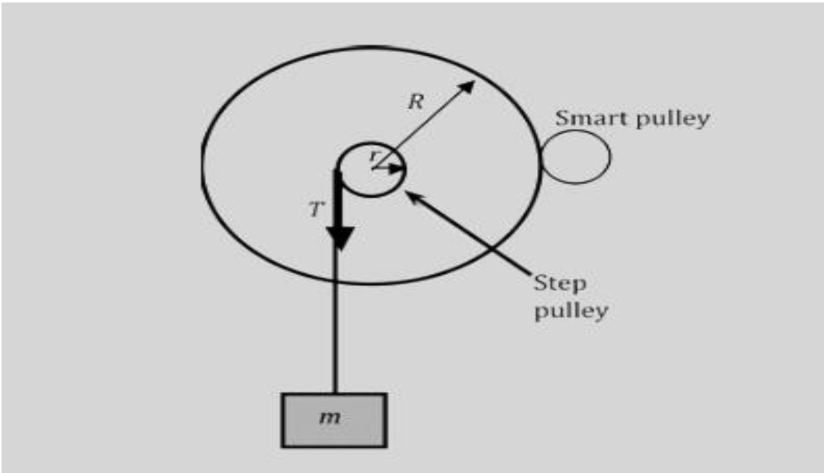
**DIAGRAM:**




**OBSERVATION:**

Radius of the axle

| Trial no. | MSR (cm) | CVD | TR=MSR+(CVD×LC) (cm) | Mean Diameter ‘d’ in cm |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

Mean Diameter d=…………X$10^{-2}$m

**ANGULAR ACCELERATION:**

| Mass in the scale pan $\times 10^{-3}$ kg | No. of revolutions (n) | Time for n revolutions in sec | | | Angular acceleration $\alpha = \frac{4\pi n}{t^2}$ rad/s$^2$ | Mean $\alpha$ rad/s$^2$ |
|---|---|---|---|---|---|---|
| | | $t_1$ | $t_2$ | Mean ‘t’ | | |
| $m_1$=50 | 2 | | | | | $\alpha_1$= |
| | 4 | | | | | |
| | 6 | | | | | |
| | 8 | | | | | |
| $m_2$=100 | 2 | | | | | $\alpha_2$= |
| | 4 | | | | | |
| | 6 | | | | | |
| | 8 | | | | | |

**CALCULATIONS:**

## EXPERIMENT NO: 01

## EXPERIMENT NAME: MOMENT OF INERTIA OF FLY WHEEL

**AIM:** To determine the moment of inertia of fly wheel and to find mass of the fly wheel.

**APPARATUS:** Fly wheel, thread, weights, stop clock, scale pan, slide clipper (vernier).

**PRINCIPLE:** The angular acceleration of a flywheel depends on the couple acting on it. By applying a known couple, the angular acceleration and hence moment of inertia is calculated.

**FORMULA:**

1) $$\mathbf{I}=\frac{(m_2-m_1)gr}{(\alpha_2-\alpha_1)} \text{ kg m}^2$$

Where $\alpha_{1,}$ $\boldsymbol{\alpha}_2$ are the angular acceleration for masses $m_1$,$m_2$ to elimimate the frictional force f.

I= moment of inertia of the fly wheel (kg/m$^2$).

r= radius of the axle of the fly wheel (m).Where $\mathbf{r}$=d/2=……………..X10$^{-2}$m

m= mass acting at distance 'r' from the axis of the fly wheel (kg).

2) $$\mathbf{M}=\frac{2I}{R^2}$$

Where, M= mass of the fly wheel (kg).

R=radius of the fly wheel (m).

**PROCEDURE:**

1) Arrange the fly wheel as shown in figure.
2) Determine the radius of the axle(r) with a slide caliper.
3) Mark a line on the fly wheel, load with mass $m_1$. It begins to rotate. Note the time 't' for number of rotations using a stop clock. Calculate $\boldsymbol{\alpha}=\frac{4\pi n}{t^2}$.
4) Repeat steps 3 for mass $m_2$.
5) Calculate $\mathbf{I}=\frac{(m_1-m_2)gr}{(\alpha_1-\alpha_2)}$.
6) Measure the circumference(c) of the fly wheel and hence radius $R=\frac{c}{2\pi}$.

**RESULT:** Moment of inertia of the fly wheel, I = ………… kg m$^2$

Mass of the fly wheel, M=…………kg

**DIAGRAM:**

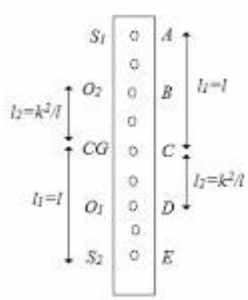



Fig 1

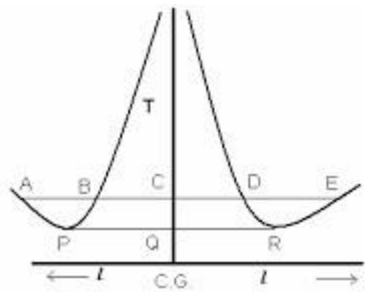



Fig. 2

**TABULAR COLUMN:**

| Hole no. | one side of centre of gravity | | | | | other side of centre of gravity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Distance from C.G (m) | Time for 20 oscillations (s) | | | Period T (s) | Distance from C.G (m) | Time for 20 oscillations (s) | | | Period T (s) |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |

**Calculations from the graph:**

| No. | Equivalent length of simple pendulum L (m) | | Mean L (m) | Period T (s) | $\left[\frac{L}{T^2}\right]$ $ms^{-2}$. |
|---|---|---|---|---|---|
| 1 | AB= | CD= | $\frac{AB + CD}{2}$ | | |
| 2 | $A^1B^1$= | $C^1D^1$= | $\frac{\mathrm{A1B1 + C1D1}}{2}$ | | |
| 3 | PQ= | QR= | PQ+QR | | |

**CALCULATIONS:**

## EXPERIMENT NO: 02

## EXPERIMENT NAME: BAR PENDULUM

**AIM:** To determine the acceleration due to the gravity at a given place using bar pendulum by graphical method.

**APPARATUS:** Bar pendulum, knife edge, stop clock, meter scale.

**PRINCIPLE:** A simple pendulum whose period is equal to the period of a given oscillating body is called equivalent simple pendulum and length as equivalent length.

When a bar pendulum execute simple harmonic motion, on one side of centre of gravity there are two positions of centered suspensions about which time periods are same similarities on other side of centre of gravity. The distance between two such a symmetry centre of suspension on either side of centre of gravity given "the value length", this is determine from the graph from which 'g' is calculated.

**FORMULA:** The acceleration due to gravity at a given place is given by
$g = 4\pi^2 \left[\frac{L}{T^2}\right] ms^{-2}$.

Where, g = acceleration due to gravity (ms$^{-2}$)

L =length of the equivalent simple pendulum (m)

T = time for oscillations (sec)

**PROCEDURE:**

**PART – A:** Determination of period of equivalent simple pendulum.

1) The bar pendulum is suspended by passing the knife edge through first hole. The distance of the hole 'h' from the centre of gravity measured using meter scale.
2) The bar pendulum is made to oscillate with a small amplitude in vertical plane. The time for 20 oscillations is calculated using $T = \frac{t}{20}$.
3) The experiment is repeated for all the holes on one side of CG. In each case, the distance of the hole from first CG is measured and readings are tabulated.
4) The pendulum is inverted and experiment is repeated for all the holes on other side of CG.
5) A graph is drawn by taking time period T along the Y – axis and distance of the hole from CG along X – axis, two curves symmetrical w.r.t Y – axis are obtained.

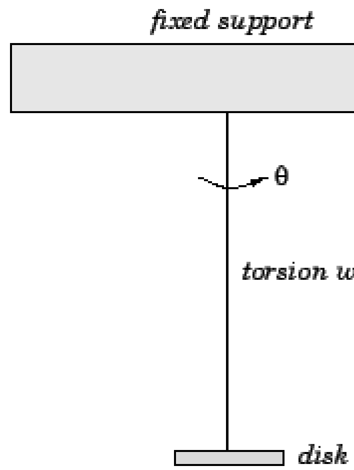
**PART – B:** Determination of equivalent length from the graph.

1) To determine the length of equivalent of simple pendulum corresponding to any period T, a line is drawn parallel to X – axis through the point on Y – axis corresponding to that period curve at A, B, C and D.
2) The distance corresponds to AB and CD are determined from the graph.
3) The length of equivalent simple pendulum is calculated by using $\alpha = \frac{AB+CD}{2}$. For that period T and hence $\frac{L}{T^2}$ is calculated $\frac{1}{T^2}$ value is determined. The men value of $\frac{1}{T^2}$ is calculated and the value of g is determined.

**<u>RESULT</u>:**

The acceleration due to gravity at the given place is:

**DIAGRAM:**




**OBSERVATION:**

Mass of the rectangular disc (M) = kg

Length of the rectangular disc (L) = m

Breadth of the rectangular disc (B) = m

| Axis | Moment of inertia I (kgm²) | Time for 20 oscillations (s) | | | | Period T (s) | $\frac{I}{T^2}$ Kgm²s⁻² |
|---|---|---|---|---|---|---|---|
| | | Trial (1) | Trial (2) | Trial (3) | Mean | | |
| Passing through the centre and perpendicular to the plane | $I=\frac{M(L^2+B^2)}{12}$ | | | | | | |
| passing through the centre and parallel to the breadth | $I=\frac{ML^2}{12}$ | | | | | | |
| passing through the centre and parallel to the length | $I=\frac{MB^2}{12}$ | | | | | | |

$K=\left(\frac{1}{T^2}\right)_{mean}=$

## OBSERVATIONS:

Thickness of the wire:

Using screw gauge:

$LC=\frac{\text{value of one pitch}}{\text{total no head scale divisions}}=$

| Tr. No. | PSR (mm) | HSR | CHSR (HSR-ZE) | TR=PSR+(CHSR×LC)=[d] (mm) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

Mean d= m

Radius of the wire r=d/2= m

## CALCULATIONS:

## EXPERIMENT NO: 03

## EXPERIMENT NAME: MOMENT OF INERTIA OF TORSIONAL PENDULUM

**AIM:** To determine the rigidity modulus of the material of given wire.

**APPARATUS:** Thin wire with different lengths, metallic disc, split, stop clock, meter scale and screw gauge.

**PRINCIPLE:** In rotational motion, moment of inertia of a body place the same role as mass is translatory motion. When set into tensional oscillations, the moment of inertia of a body about its axis of suspension is directly proportional to the square of its period of oscillations about the same axis.

**FORMULA:**

(1) **For a rectangular plate:**

(a) Moment of inertia about an axis passing through the centre and perpendicular to the plane:

$$I=\frac{M(L^2+B^2)}{12} \quad (\text{kgm}^2)$$

(b) Moment of inertia about an axis passing through the centre and parallel to the breadth:

$$I=\frac{ML^2}{12} \quad (\text{kgm}^2)$$

(c) Moment of inertia about an axis passing through the centre and parallel to the length:

$$I=\frac{MB^2}{12} \quad (\text{kgm}^2)$$

(2) **Couple per unit twist for given wire:**

$$C=4\pi^2 K \qquad \text{here } K=\frac{1}{T^2}$$

Where T=period of torsional oscillations of the disc(s)

(3) **Rigidity modulus of the material of the given wire:**

$$\eta=\frac{2lC}{\pi r^4}$$

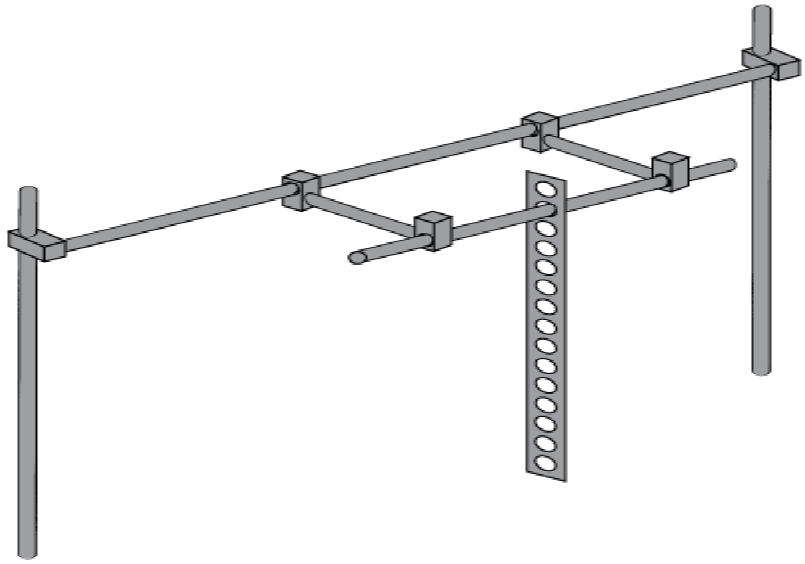
Where r= radius of the wire (m).

**PROCEDURE:**

(1) Measure the mass of the rectangular disc(M) using a scale pan.
(2) Measure the length(L) and breadth(B) of the rectangular disc using meter scale.
(3) Calculate the moment of inertia of the disc using formula (1).
(4) The disc is hang from an iron stand by means of the given wire along different axes. The system is made to execute torsional oscillations and the mean period T is calculated using a stop watch each time.
(5) $\frac{1}{T^2}$ is calculated in each case and the mean value K is determined.
(6) Couple per unit twist of the wire using the formula (2).
(7) Measure the radius of the wire (r) using screw guage.
(8) Measure the length of the wire (l) using a meter scale.
(9) Calculate the rigidity modulus of the material of the wire using the formula (3).

**RESULT:** The rigidity modulus of the material of the wire is -------------------

**DIAGRAM:**



**OBSERVATIONS:**

Mass of the bar pendulum:

Length of the bar pendulum:

Acceleration due to gravity (g) = 9.8$ms^{-2}$

Moment of inertia of the bar pendulum about an axis passing through its centre of gravity and parallel to the axis of suspension:

$\mathbf{I_0=\frac{ML^2}{12}} =$

$I_0$=

| Hole no. | Distance from CG X (m) | Time for 20 oscillations (s) | | | | Period T (s) | Experimental value $I=\frac{Mg x T^2}{4\pi^2}$ | Theoretical Value $I=I_0+Mx^2$ |
|---|---|---|---|---|---|---|---|---|
| | | Trial(1) | Trial(2) | Trial(3) | mean | | | |
| 2 | | | | | | | | |
| 4 | | | | | | | | |
| 6 | | | | | | | | |
| 8 | | | | | | | | |

**CALCULATIONS:**

## EXPERIMENT NO: 04

## EXPERIMENT NAME: PARALLEL AXES THEOREM

**AIM:** To verify the parallel axes theorem of moment of inertia.

**APPARATUS:** Bar pendulum, meter scale, stop clock etc.

**PRINCIPLE: Theorem of parallel axes:** The moment of inertia of a body about any axes is equal to the sum of the moment of inertia of the body about a parallel axes to the centre of mass and the product of the mass of the body and the square of the perpendicular distance between the two axes.

**FORMULA:**

(1) Moment of inertia of the bar pendulum about an axis passing through its centre of gravity and parallel to the axes of suspension:

$$I_0=\frac{ML^2}{12} \text{ (kgm}^2\text{)}$$

Where M= mass of the bar pendulum (kg)
L= length of the bar pendulum (m)

(2) Moment of inertia of the bar pendulum about an axis parallel to the axis passing through the centre of gravity:

$$I=\frac{MgxT^2}{4\pi^2} \quad \text{(kgm}^2\text{)}$$

Where M=mass of the bar pendulum (kg)
g=acceleration due to gravity at the place (9.8ms$^{-2}$)
x=distance of the axis of rotation from the CG (m)
T=period of oscillation(s)

(3) Moment of inertia:

$$I=I_0+Mx^2$$

**PROCEDURE:**

(1) The mass of the bar pendulum (M) is determined using a balance.
(2) The length of the bar pendulum (L) is determined using a meter scale.
(3) The moment of inertia of the bar pendulum about an axis passing through its centre of gravity and parallel to the axis of suspension ($I_0$) is calculated using the formula (1).
(4) The position of centre of gravity of the bar pendulum is marked. Hole numbers are counted with this as reference. The distance(x) of the holes 2, 4, 6 and 8 on one side are measure from CG.
(5) The knife edge is fixed to the 2$^{nd}$ hole and the bar pendulum is suspended over a supporting. The pendulum is made to oscillate in a vertical plane with small amplitude.

The time for 20 oscillations is noted separately for 3 trials. The mean time and hence the period (T) is calculated.

The moment of inertia of the bar pendulum about an axis parallel to the axis passing through the centre of gravity (I) is calculated using formula (2).

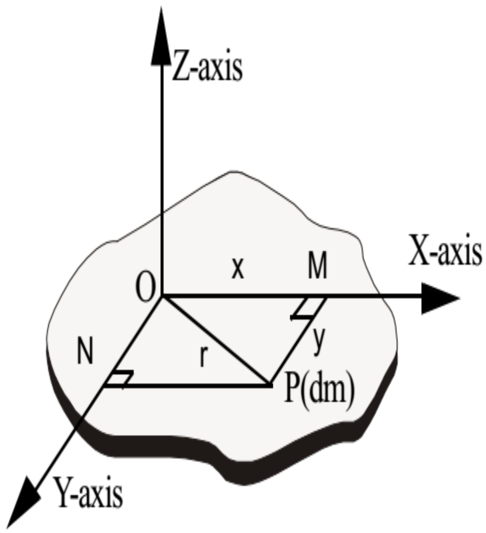
(6) The experimental value of I is compared with the theoretical value obtained using the formula (3).
(7) The experiment is repeated for the holes 4, 6 and 8. The readings are tabulated.

**RESULT:**

| Hole no. | Experimental value | Theoretical |
|---|---|---|
| 2 | | |
| 4 | | |
| 6 | | |
| 8 | | |

The moment of inertia of the bar pendulum about an axis parallel to the axis passing through the centre of gravity obtained experimentally is found to be in good agreement with that of the theoretical. Hence parallel axes theorem is verified.

**DIAGRAM:**




**OBSERVATIONS:**

**To find moment of inertia of rectangular plate:**

| Axis | Body | Time for 20 oscillations (s) | | | | Time for 20 Oscillations ‘t’ (s) | Time Period T=t/20 | Mean ‘T’ (s) |
|---|---|---|---|---|---|---|---|---|
| | | No. of Oscill ations | Time (s) | No. of Oscillations | Time (s) | | | |
| Passing through the centre and perpendicular to the plane | | 0 | | | | | | $T_Z$ |
| | | 5 | | | | | | |
| | | 10 | | | | | | |
| | | 15 | | | | | | |
| passing through the centre and Perpendicular to the breadth | | 0 | | | | | | $T_y$ |
| | | 5 | | | | | | |
| | | 10 | | | | | | |
| | | 15 | | | | | | |
| passing through the centre and Perpendicular to the length | | 0 | | | | | | $T_x$ |
| | | 5 | | | | | | |
| | | 10 | | | | | | |
| | | 15 | | | | | | |

$T_Z$=

$T_X+T_Y$=

## EXPERIMENT NO: 05

## EXPERIMENT NAME: PERPENDICULAR AXES THEOREM

**AIM:** To verify the perpendicular axes theorem and moment of inertia.

**APPARATUS:** Bar pendulum, rectangular plate, stand, stop clock, etc

**PRINCIPLE:** **Theorem of the perpendicular axes:** The moment of inertia of plane laminar body about an axes perpendicular to its plane is equal to the sum of the moments of inertia about two mutually perpendicular axes in the plane of the lamina such that the three mutually perpendicular axes have a common point of intersection.

**FORMULA:** (1) **for rectangular plate**

(a) Moment of inertia about an axis perpendicular to the plane of the plate $T_Z$
(b) Moment of inertia about an axis parallel to the breadth of the plate $T_X$
(c) Moment of inertia about an axis parallel to the length of the plate $T_Y$
Hence $T_Z^2=T_X^2+T_Y^2$ since $I \alpha T$ where **I** is moment of Inertia of a rigid body about the axis of rotation

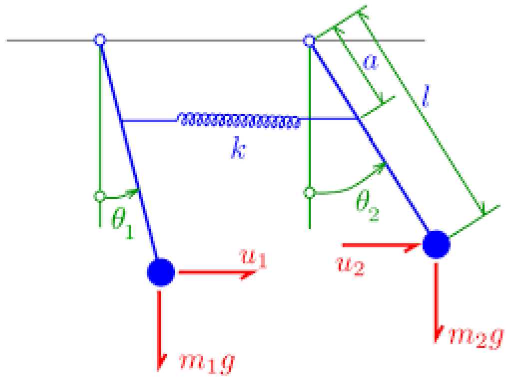
**PROCEDURE:**

(1) Suspend the Rectangular Plate as shown in figure.
(2) Set into torsional oscillations and determine the period of oscillations.
(3) Repeat steps 1,2 for different axis and different axis.
(4) Verify $T_Z^2=T_X^2+T_Y^2$.

**RESULT:**

Experimentally it is found that $T_Z^2=T_X^2+T_Y^2$ for a rectangular plate and hence perpendicular axis theorem is verified

**DIAGRAM:**




**OBSERVATIONS:**

**In phase mode:**

| Tr no | Coupling distance (cm) | Time for 20 oscillations (s) | | | | $T_1=t/20$ (s) | $f_1=\frac{1}{T1}$ (Hz) |
|---|---|---|---|---|---|---|---|
| | | $t_1$ | $t_2$ | $t_3$ | $t_{mean}$ | | |
| 1 | | | | | | | |
| 2 | | | | | | | |

**Out phase mode:**

| Tr. No | Coupling distance (cm) | Time for 20 oscillations (s) | | | | $T_1=t/20$ (s) | $f_1=\frac{1}{T1}$ (Hz) | $f_b=f_1\sim f_2$ (Hz) |
|---|---|---|---|---|---|---|---|---|
| | | $t_1$ | $t_2$ | $t_3$ | $t_{mean}$ | | | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |

| Time for one cycle of energy transfer t (s) | Period of energy transfer t (s) | Frequency $f_s=1/t$ (Hz) |
|---|---|---|
| | | |
| | | |

## EXPERIMENT NO:06

## EXPERIMENT NAME: COUPLED OSCILLATOR

**AIM:** 1) To demonstrated the effect of coupling in the behavior of individual oscillators.

2) To find the frequency of normal modes (both in and out of phase).

3) To find the frequency of energy transfer.

**APPARATUS:** Two identical bobs, inexentensible threads, digital stop watch, scale etc.

**PRINCIPLE:** If two oscillators A and B have an interaction between them, they are said to form a coupled system. In this coupled system neither of them oscillates harmonically, except in two situations. These situations are called normal modes viz "in phase (zero phase difference)" and "out of phase (phase difference of π)" modes.

The common frequency of oscillation when the two oscillators oscillate in phase is $f_1$. The common frequency of oscillation when the two oscillators oscillate in out of phase is $f_2$. The difference in the frequencies of two modes is called beat frequency ($f_b=f_1 \sim f_2$). It is very important to study oscillations of coupled system because coupling leads to phenomenon of wave motion.

**FORMULA:**

1. Frequency of oscillation when the bobs are in phase:

$$\mathbf{f_1}=\frac{1}{T1} \quad \text{Hz}$$

where T1= period of oscillations of the coupled oscillators which are in phase(s)

2. Frequency of oscillation when the bobs are out of phase:

$$\mathbf{f_2}=\frac{1}{T2} \quad \text{Hz}$$

where T2= period of oscillations of the coupled oscillators which are out of phase(s)

3. Beat frequency $\mathbf{f_b=f_1 \sim f_2}$ Hz
4. Frequency of energy transfer

$$\mathbf{f}_3=\frac{1}{T3} \quad \text{Hz}$$

where T3= energy transfer time for one cycle(s)

**PROCEDURE:**

1. The experimental arrangement is made as shown in the figure.
2. Chose a certain length 'L' of the pendulum and coupling distance 'x'.

**Part-01:** for 'in phase' normal mode

3. Displace the bobs equally in the same direction and release them simultaneously such that they oscillate in a plane.
[Take care that both pendulums should maintain same frequency and amplitude ratio]

4. Record the time for 20oscillations thrice and calculated the mean value. Calculate the period (T1) and hence the frequency $f_1$.

**Part-02:** for 'out of phase' normal mode

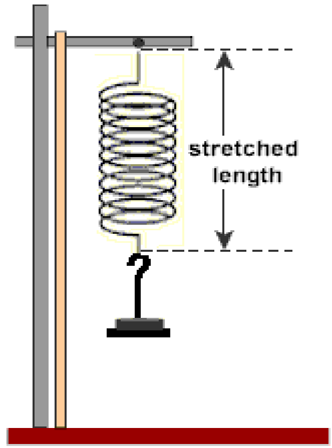
5. Without changing the coupling distance and the length of the coupling system, displace the bobs equally in the opposite direction and release them simultaneously such that they oscillate in a plane.
6. Record the time for 20 oscillations thrice and calculated the mean value. Calculate period (T2) and hence the frequency $f_2$.
7. Calculate the beat frequency corresponding to normal mode: $f_b=f_1{\sim}f_2$

**Part-03:**for energy transfer

8. place the bob 'A' at rest. Displace the bob 'B' and release.[the amplitude of the bob 'B' slowly decreases and comes to rest momentarily. In the mean time the energy transfer will takes from bob 'B' to the bob 'A'. Hence the bob 'A' will pick up oscillations. The oscillations of the b0b 'A' increases-becomes maximum-decreases and becomes zero momentarily. Next the bob 'B' picks up the oscillations and the process goes on. The event between any two conclusive zero amplitudes of a bob is equal to one cycle of energy transfer for the bob].
9. Note down the energy transfer time for the bob (say B) for 5 consecutive cycles of energy transfer thrice and fine the mean time. Calculate the beat period T3 (I.e time for one cycle) and hence the frequency of energy transfer ($f_3$ ) using the formula (4).
10. Repeat the experiment for two lengths (L) and two coupling distances(x).

**RESULT:** The beat frequency $f_b$ corresponding to the normal modes is found equal to the frequency of energy transfer within the experimental limits.

**DIAGRAM:**



## EXPERIMENT:07

## EXPERIMENT NAME: g BY SPIRAL SPRING

**AIM:** To determine the acceleration due to gravity by using a spiral spring.

**APPARATUS:** spiral spring, scale pan, stop watch, meter scale, weights, stand.

**PRINCIPLE:** The **helical spring**, is the most commonly used mechanical **spring** in which a wire is wrapped in a **coil** that resembles a screw thread. ... **Helical spring** works on the **principle** of Hooke's Law. Hooke's Law states that within the limit of elasticity, stress applied is directly proportional to the strain produced.

**FORMULA:**

1) $\mathbf{g} = 4\Pi^2(x/T^2)$ cm/sec$^2$

   **g** is acceleration due to gravity
   **x** is Extension in spring
   **T** is Time period for 20 vibrations

2) Extension $\mathbf{x} = x_2 - x_1$ (cm)
   $\mathbf{x_1}$= initial pointer reading

   $\mathbf{x_2}$ = final pointer reading

3) Percentage Error = Differenc/Original X 100
   = ( 980-$\mathbf{g_{mean}}$ / 980 ) X 100

**PROCEDURE:**

- Make the experimental set up
- Add load in steps of 50 gms for each trial
- Determine the initial ($x_1$) cm and final ($x_2$) cm pointer reading
- Find the extension in the spring by using the formula $\mathbf{x} = x_2 - x_1$ (cm)
- Determine the time period (T) for 20 vibrations
- Finally find the value of **'g'**

**RESULT:** Acceleration due to gravity by spiral spring is g = ………ms$^{-2}$

**Tabular Column :**

| Trial no. | Load Suspended in **M (gm)** | Pointer reading | | Extension in spring $X = X_2 - X_1$ (cm) | Time for 20 vibrations | | | Time Period $T = t/20$ (secs) | $T^2$ ($sec^2$) | $g = 4\Pi^2(x/T^2)$ ($cm/sec^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $X_1$**(cm)** | $X_2$**(cm)** | | $t_1$ (secs) | $t_2$ (secs) | $t = t_1 + t_2/2$ (secs) | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

$g_{mean}$ =

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