Determine the spring constant using Static and Dynamic Method

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AIM: To find spring constant of a spring by
(1) Static method
(2) Dynamic method
and also find value of acceleration due to gravity and modulus of rigidity.

APPARATUS REQUIRED: Telescope, Stop-watch, the given spring with vertical scale, load of unknown masses.

THEORY: $T = 2\pi\sqrt{\dfrac{m+m_0}{k}}$

where, m_0 and m are the masses of spring and suspended load respectively and k is spring factor of given spring.

$$T_1 = 2\pi\sqrt{\frac{m_0+m_1}{k}} \quad \text{--- (1)}, \qquad T_2 = 2\pi\sqrt{\frac{m_0+m_2}{k}} \quad \text{--- (2)}$$

On squaring and adding,

$$k = \frac{4\pi^2(m_1-m_2)}{T_1^2-T_2^2}, \qquad k = \frac{4\pi^2(m_2-m_3)}{T_2^2-T_3^2}$$

and T_1 and T_2 are the time period of oscillation when loads are m_1 and m_2 respectively.

PROCEDURE:

Statical method: (1) Hang the spring AB vertically from a rigid support. The lower end of the spring should have a hanger or a scale-pan with a pointer attached to it. Set up a metre scale vertically with the help of a stand and a clamp so that the position of the pointer can be read on it.

Teacher's Signature

Take care that the scale is not touching the pointer.
(2) With no load in the pan, note down reading of the pointer.
(3) Gently place a load of 1/2 kg in the pan and note down the pointer reading.
(4) Gradually increase the load in steps of 1/2 kg and note down the corresponding pointer till the load in the pan is about 3 kg.
(5) Now decrease the load gradually in steps of 1/2 kg and note down the pointer reading. Find mean extension l for each load.
(6) Plot a graph between the load M along x-axis and the extention l along y-axis.

Dynamical method:
(1) Place a load of 1/2 kg in the pan. Pull the pan vertically to give a small displacement and then release it. Note down the time for 25 vibrations. ~~then~~ Repeat the observation for the same load and find mean time-period T.
(2) Increase the load in the pan in steps of 1/2 kg and each time note down the time for 25 vibrations twice and find the mean time-period T.
(3) Plot the graph between load M along x-axis and T^2 along y-axis.

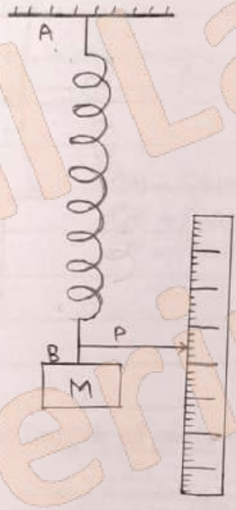
Experiment - 1

AIM: To find the spring constant of a spring by

(1) static method (2) dynamic method

also find value of acceleration due to gravity and modulus of rigidity.

DIAGRAM:



FORMULA USED:

To calculate, $k = \frac{4\pi^2(m_1-m_2)}{T_1^2-T_2^2}$

To calculate acceleration due to gravity, $g = \frac{kl}{M}$

To calculate modulus of rigidity, $n = \frac{2LR^2k}{\pi r^4}$

OBSERVATIONS:

Reading with no mass, $x_1 = 0$ cm

least count of stop-watch = 0.01 sec

(1) Statical method :

S.No	Mass suspended (gm)	Load $\uparrow$sing (cm)	Load $\downarrow$sing (cm)	(x_2) mean reading (cm)	Extension $l = x_2 - x_1$ (cm)	Force (mg)
1.	50	1.3	1.3	1.3	1.3	490
2.	100	2.7	2.7	2.7	2.7	980
3.	150	4.3	4.3	4.3	4.3	1470
4.	200	5.8	5.8	5.8	5.8	1960
5.	250	7.4	7.4	7.4	7.4	2450

(2) Dynamical method :

S.No	Load mass (kg)	Time for 25 vibrations t_1(s)	t_2(s)	Time period $T = (t_1+t_2)/50$ (s)	T^2 (s^2)
1.	0.5	13	12	0.5	0.25
2.	1.0	14	14	0.56	0.3136
3.	1.5	15	15	0.6	0.36
4.	2.0	16	16	0.64	0.4096
5.	2.5	18	18	0.72	0.5184

CALCULATIONS :

(1) Statical method :

$$kl = mg \Rightarrow k = mg / l$$

$$k_1 = \frac{m_1 g}{l_1} = \frac{490}{1.3} \times \frac{1000}{1000} = 37.69\ Nm^{-1}$$

$$k_2 = \frac{m_2 g}{l_2} = \frac{980}{2.7 \times 10} = 36.29\ Nm^{-1}$$

$$k_5 = \frac{2450}{74} = 33.10\ Nm^{-1}$$

$$k_3 = \frac{m_3 g}{l_3} = \frac{1470}{43} = 34.18\ Nm^{-1}$$

$$k_4 = \frac{m_4 g}{l_4} = \frac{1960}{58} = 33.79\ Nm^{-1}$$

$$k = \frac{k_1 + k_2 + k_3 + k_4 + k_5}{5} = \frac{37.69 + 36.29 + 34.18 + 33.79 + 33.16}{5}$$

$$\boxed{k = 35.01 \text{ Nm}^{-1}}$$

(2) Dynamical method:

$$k_1 = \frac{4\pi^2(m_1 - m_2)}{T_1^2 - T_2^2} = \frac{4 \times (3.14)^2 \times 0.5 \times 10^{-1}}{0.3136 - 0.25} = 32.51 \text{ Nm}^{-1}$$

$$k_2 = \frac{4 \times (3.14)^2 \times 0.5}{0.4096 - 0.36} = 49.38 \text{ Nm}^{-1}$$

$$k_3 = \frac{4 \times (3.14)^2 \times 0.5}{0.72 - 0.64} = 32.92 \text{ Nm}^{-1}$$

$$k = \frac{k_1 + k_2 + k_3}{3} = \frac{32.51 + 49.38 + 32.92}{3}$$

$$\boxed{k = 38.27 \text{ Nm}^{-1}}$$

Acceleration due to gravity:

(1) Statical method:

$$Mg = kl$$

$$g = \frac{kl}{M} = \frac{35.01 \times 5}{150} \times \frac{1000}{100}$$

$$\boxed{g = 9.58 \text{ m/sec}^2}$$

(2) Dynamical method:

$$g = \frac{38.27 \times 5}{150} \times \frac{1000}{10}$$

$$\boxed{g = 9.75 \text{ m/sec}^2}$$

Statical method

Slope = $\frac{BC}{AC} \times 10^{-2}$

Slope = 32.5×10^{5}

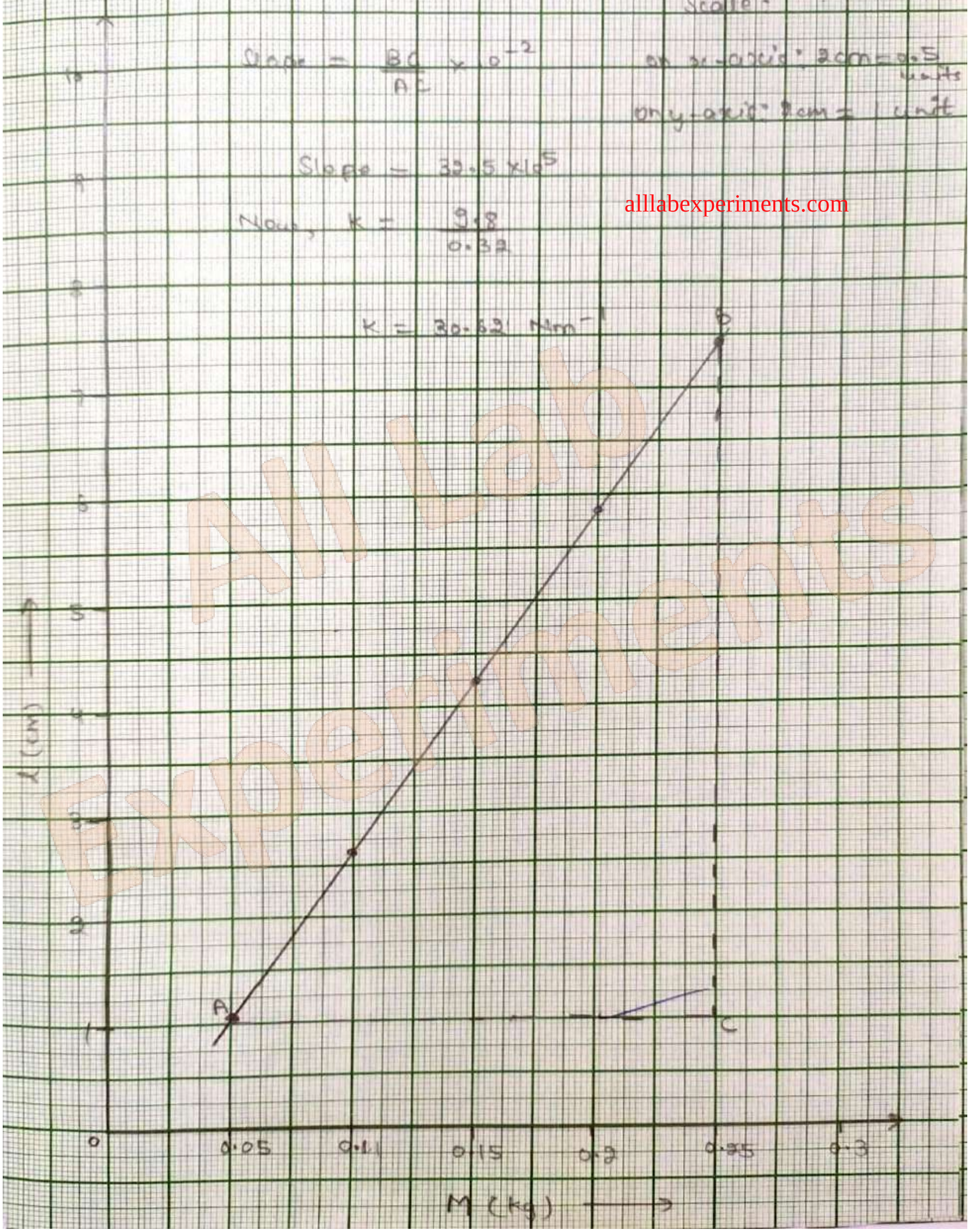
Now, $k = \frac{9.8}{0.32}$

$k = 30.62\ Nm^{-1}$

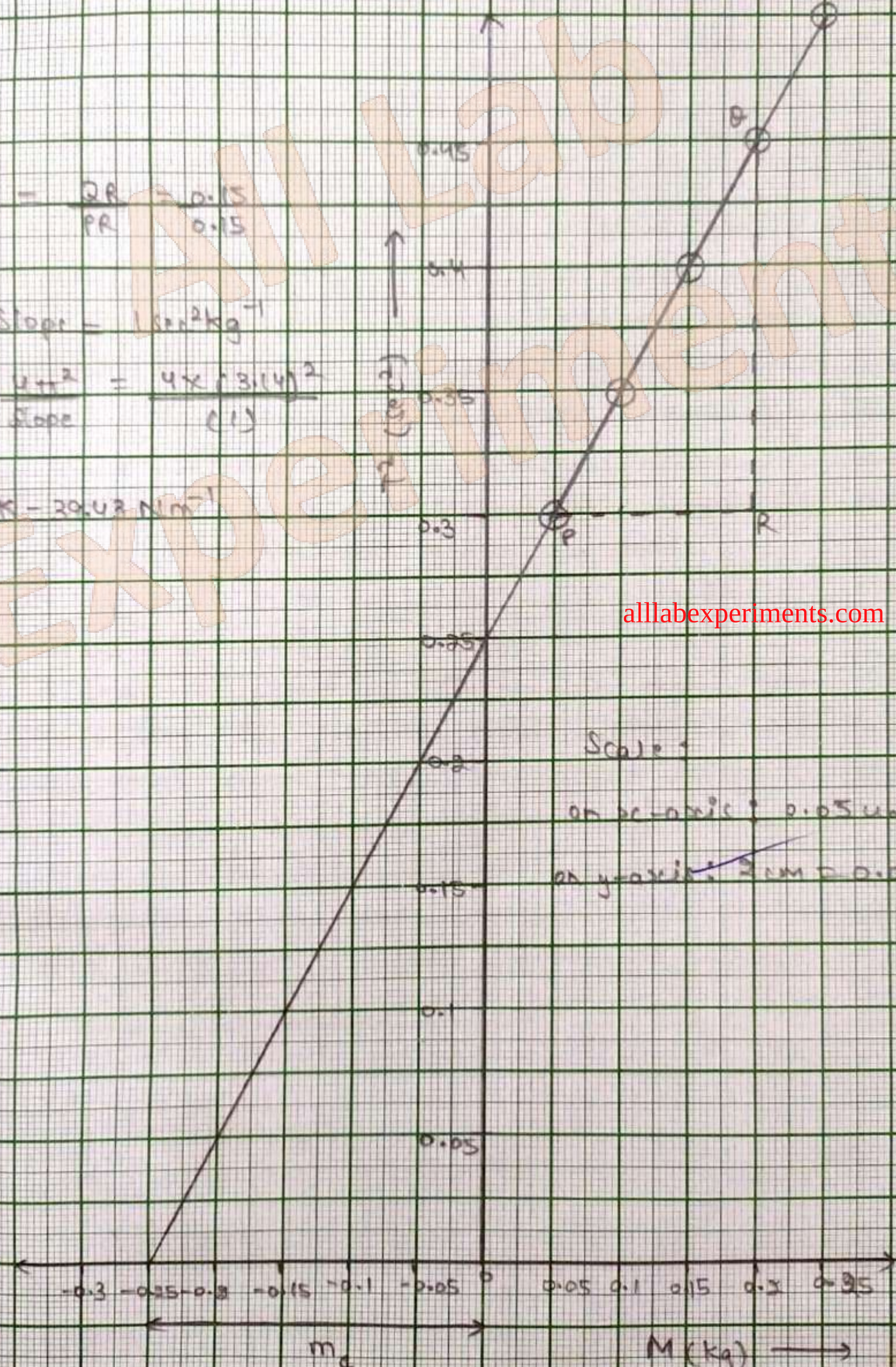
Scale:-

on x-axis: 2cm = 0.5 units

on y-axis: 2cm = 1 unit



Dynamical method



$$\text{Slope} = \frac{QR}{PR} = \frac{0.15}{0.15}$$

$$\text{Slope} = 1\ s^2 kg^{-1}$$

$$k = \frac{4\pi^2}{\text{Slope}} = \frac{4 \times (3.14)^2}{(1)}$$

$$k = 39.43\ Nm^{-1}$$

Scale :

on x-axis : 0.05 units = 1cm

on y-axis : 2cm = 0.05 units

RESULT :

The spring constant k of spring
= $35.01\ Nm^{-1}$ by statical method
= $38.27\ Nm^{-1}$ by dynamical method

PRECAUTIONS AND SOURCES OF ERROR :

(1) The axis of the spring should be vertical.
(2) The scale should be vertical and should not touch the pointer.
(3) The spring should not be stretched beyond the elastic limit.

(4) The amplitude of vertical oscillations should be small.
(5) The spring should oscillate vertically and any other motion should not be there.
(6) The time-period of oscillations should be accurately measured as they occur in the second-power.