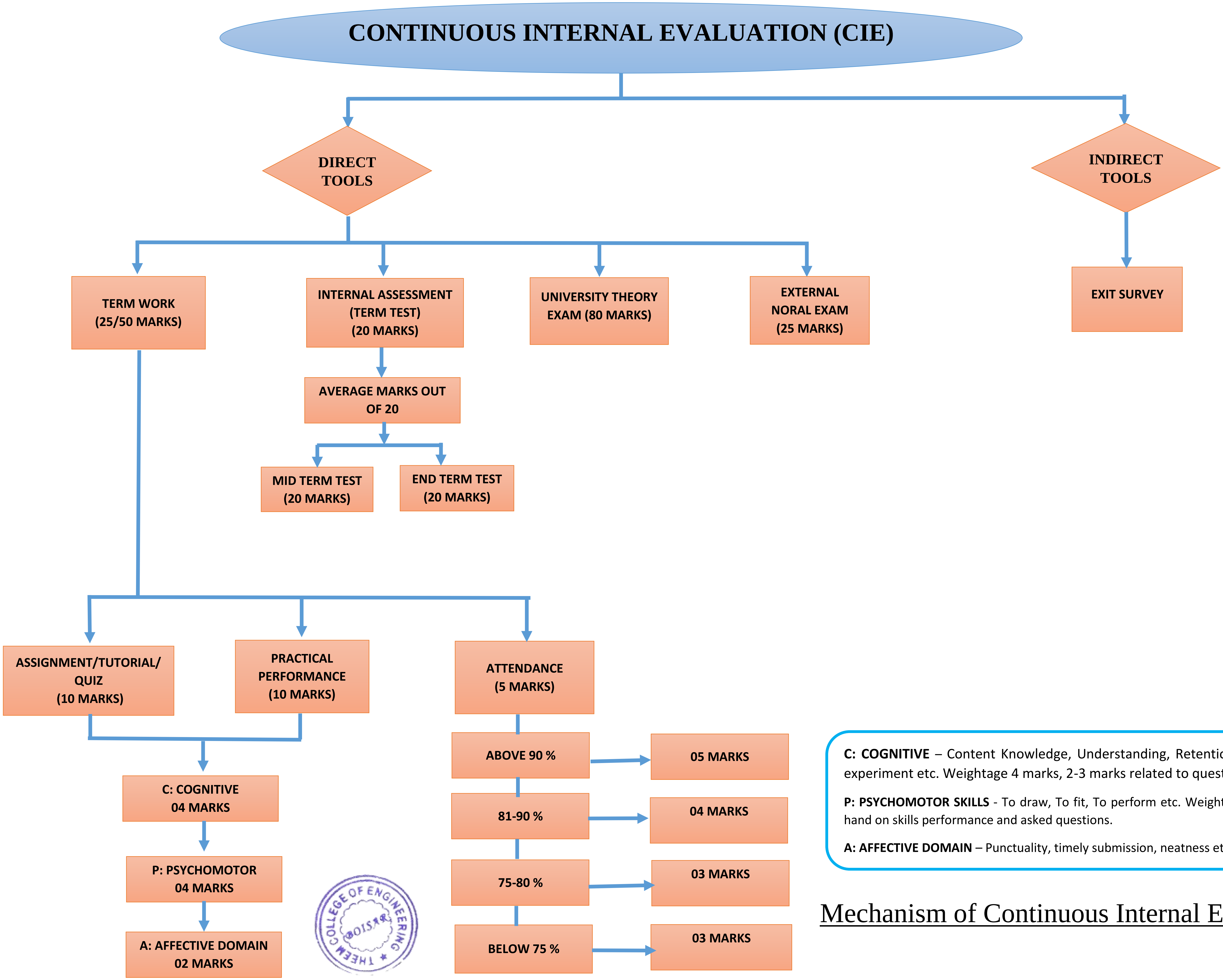


C: COGNITIVE – Content Knowledge, Understanding, Retention parameter of the experiment etc. Weightage 4 marks, 2-3 marks related to question to be asked.

P: PSYCHOMOTOR SKILLS - To draw, To fit, To perform etc. Weightage 4 marks. Observe hand on skills performance and asked questions.

A: AFFECTIVE DOMAIN – Punctuality, timely submission, neatness etc. Weightage 2 marks

Mechanism of Continuous Internal Evaluation (CIE)

Continuous assessment

(Experiment /Assignment / Tutorial /Project activity etc.)

- ❖ Candidate shall be assessed continuously for his sincerity, punctuality, and discipline along with the understanding of facts, principles, theories and application.
- ❖ Term Work and presentation for each practical made by candidates shall be assessed on following parameters.

C: Cognitive – Content Knowledge, Understanding, Retention parameters of the experiment etc. (2-3 related questions to be asked)

Weightage: 4 marks

P: Psychomotor Skills – To draw, to fit, to perform etc. Observe hands on skills performance & ask questions.

Weightage: 4 marks

A: Affective Domain – Such as punctuality, Timely submissions, Neatness etc,

Weightage: 2marks.

Parameter	**C**	**P**	**A**	**Total**	**Sign. With Date**
Marks Obtained					
Max. Marks	4	4	2	10	

1. Each practical should be assessed for maximum of 10 marks.
2. Total marks of practical work are calculated at the end of the term and converted to a base as per teaching Examination Scheme.
3. Record of continuous assessment of candidates should be maintained by lecturer in charge and kept in the custody of Head of the Department after completion of the term.
4. Marks obtained by candidate after assessment of each practical work shall be shown to candidate for improvement in subsequent practical.
5. **Term work marks** shall be revealed to the student. Marks obtained by the student in term work after continuous assessment shall be displayed on the notice board and the same shall be sent to University of Mumbai.

Experiment No. 4: Determination of Angle of Divergence of Laser Beam

Aim:

To determine the angle of divergence of laser beam using He-Ne laser and Semiconductor laser and to find out which laser is highly directional

Apparatus:

He-Ne laser, Semiconductor laser, optical bench, screen and ruler.

Theory:

Laser

The term LASER is the acronym for Light Amplification by Stimulated Emission of Radiation. It is a mechanism for emitting electromagnetic radiation via the process of stimulated emission. The laser was the first device capable of amplifying light waves themselves. The emitted laser light is a spatially coherent, narrow low-divergence beam. When the waves (or photons) of a beam of light have the same frequency, phase and direction, it is said to be coherent. There are lasers that emit a broad spectrum of light, or emit different wavelengths of light simultaneously. According to the encyclopedia of laser physics and technology, beam divergence of a laser beam is a measure for how fast the beam expands far from the beam waist. A laser beam with a narrow beam divergence is greatly used to make laser pointer devices. Generally, the beam divergence of laser beam is measured using beam profiler.

Lasers usually emit beams with a Gaussian profile. A Gaussian beam is a beam of electromagnetic radiation whose transverse electric field and intensity (irradiance) distributions are described by Gaussian functions.

For a Gaussian beam, the amplitude of the complex electric field is given by

$$E(r,z) = E_0 \frac{w_0}{w_{(z)}} \exp\left(\frac{-r^2}{w^2_{(z)}}\right) \exp\left(-ikz - ik\frac{r^2}{2R_{(z)}} + i\zeta(z)\right)$$

where,

r - radial distance from the centre axis of the beam

z - axial distance from the beam's narrowest point

i - imaginary unit (for which $i^2 = -1$)

k - wave number (in radians per meter).

$w_{(z)}$ - radius at which the field amplitude drops to 1/e and field intensity to $1/e^2$ of their axial values, respectively.

$w_{(0)}$ - waist size.

$E_0 = |E_{(0,0)}|$

$R_{(z)}$ - radius of curvature of the beam's wavefronts

$\zeta_{(z)}$ - Gouy phase shift. It is an extra contribution to the phase that is seen in beams which obey Gaussian profiles.

The corresponding time-averaged intensity (or irradiance) distribution is

$$I(r,z)=\frac{|E(r,z)|^2}{2\eta}=I_0\left(\frac{w_0}{w_{(z)}}\right)^2\exp\left(\frac{-2r^2}{w_{(z)}^2}\right)$$

where $I_0 = I_{(0,0)}$ is the intensity at the center of the beam at its waist. The constant η is defined as the characteristic impedance of the medium through which the beam is propagating. For vacuum

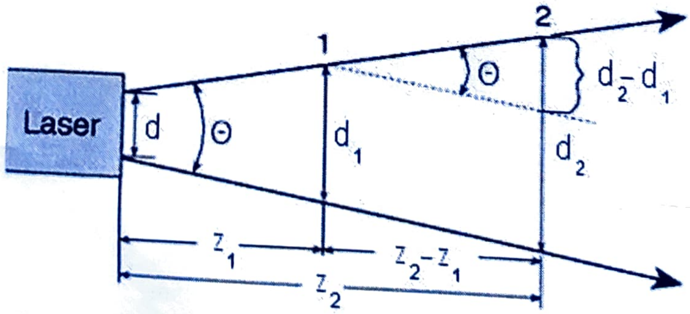
$$\eta=\eta_0\approx 377\ ohm$$

Beam parameters

Beam parameters govern the behaviour and geometry of a Gaussian beam. The important beam parameters are described below.

Beam divergence

The light emitted by a laser is confined to a rather narrow cone. But, when the beam propagates outward, it slowly diverges or fans out. For an electromagnetic beam, beam divergence is the angular measure of the increase in the radius or diameter with distance from the optical aperture as the beam emerges.



The divergence of a laser beam can be calculated if the beam diameter d_1 and d_2 at two separate distances are known. Let z_1 and z_2 are the distances along the laser axis, from the end of the laser to points "1" and "2".

Usually, divergence angle is taken as the full angle of opening of the beam. Then,

$$\Theta = \frac{d_2 - d_1}{z_2 - z_1}$$

Half of the divergence angle can be calculated as

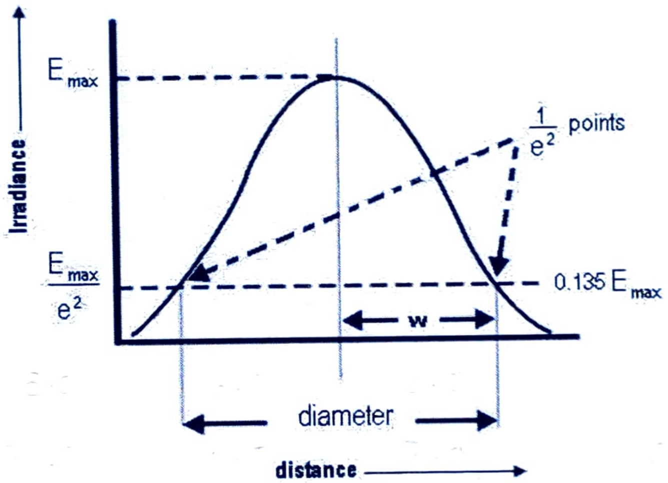
$$\theta = \frac{w_2 - w_1}{z_2 - z_1}$$

where w_1 and w_2 are the radii of the beam at z_1 and z_2.

Like all electromagnetic beams, lasers are subject to divergence, which is measured in milliradians (mrad) or degrees. For many applications, a lower-divergence beam is preferable.

Spot size

Spot size is nothing but the radius of the beam itself. The irradiance of the beam decreases gradually at the edges.



The distance across the center of the beam for which the irradiance (intensity) equals $1/e^2$ of the maximum irradiance ($1/e^2 = 0.135$) is defined as the beam diameter. The spot size (w) of the beam is defined as the radial distance (radius) from the center point of maximum irradiance to the $1/e^2$ point.

Gaussian laser beams are said to be diffraction limited when their radial beam divergence is close to the minimum possible value, which is given by

$$\theta = \frac{\Theta}{2} = \frac{\lambda}{\pi w_0}$$

where λ is the wavelength of the given laser and w_0 is the radius of the beam at the narrowest point, which is termed as the beam waist.

Procedure:

1. The experimental setup used to find the angle of divergence of the laser beam isshown as in fig.1.
2. The laser beam from He-Ne is made to fall on the screen which is kept at a distance of d1 from the source.
3. The spot size of the beam is noted and is taken as a1.
4. Now the position of the screen is altered to a new position d2 from the laser source and again the spot size of the beam is noted as a2.
5. The same procedure is repeated by changing the position of the screen at equal intervals atleast 5 times.
6. The readings corresponding to the position of the screen and spot size of the beam is tabulated.
7. From this, the angle of divergence of the laser beam is calculated using the formula $\Phi = (a2-a1)/(d2-d1)$ radians
8. Plot the graph of spot size(an) vs distance between source and screen (dn).Find slope of the graph.

Observation Table:

Measurement of angle of divergence using He-Ne laser

Sr. No.	Distance between laser beam and screen (dn) cm	Diameter of the spot (Horizontal) cm	Diameter of the spot (Vertical) cm	Mean Diameter of the spot (an) cm	$\varphi = (a_n-a_{n-1})/(d_n-d_{n-1})$ radians
1.	80	0.3	0.3	0.3	—
2.	160	0.5	0.4	0.45	1.88×10^{-3}
3.	240	0.6	0.5	0.55	1.25×10^{-3}
4.	320	0.8	0.7	0.75	2.55×10^{-3}
5.	400	0.8	1.0	0.9	1.88×10^{-3}
6.	480	1	1	1	1.88×10^{-3}

Mean = 1.88×10^{-3}

Formula:

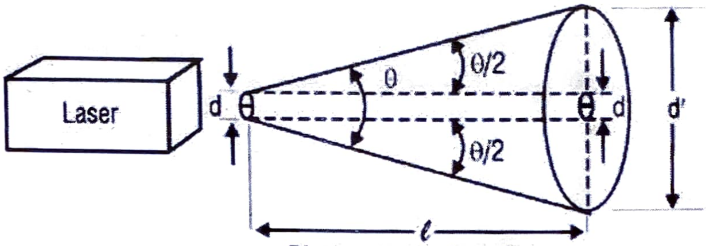
Angle of divergence of the laser beam, $\Phi = (a2 - a1)(d2 - d1)\ m$

Where, d1 is the distance between laser source and the screen in m

a1 is the spot size of the laser beam on the screen for distance d1in m

d2 is the new distance between laser source and the screen in m

a2 is the spot size of the laser beam on the screen for distance d2 in m



Divergence of a laser beam

Calculation:

Distance between laser source and the screen (d1)=..........80..........cm

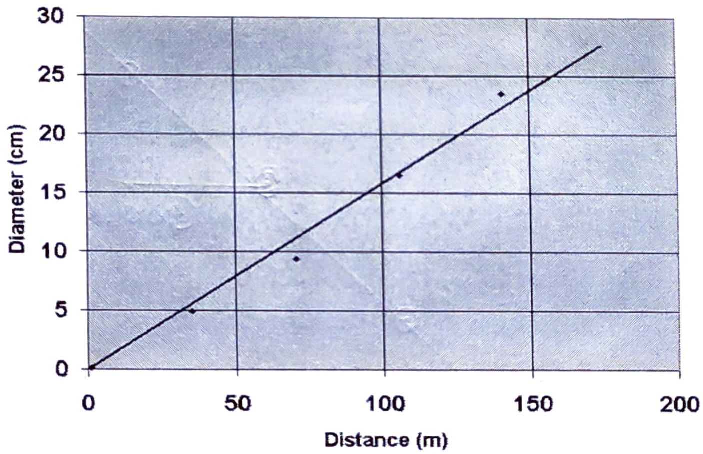
Spot size of the laser beam on the screen for distance d1 (a1)=..........0.30..........cm

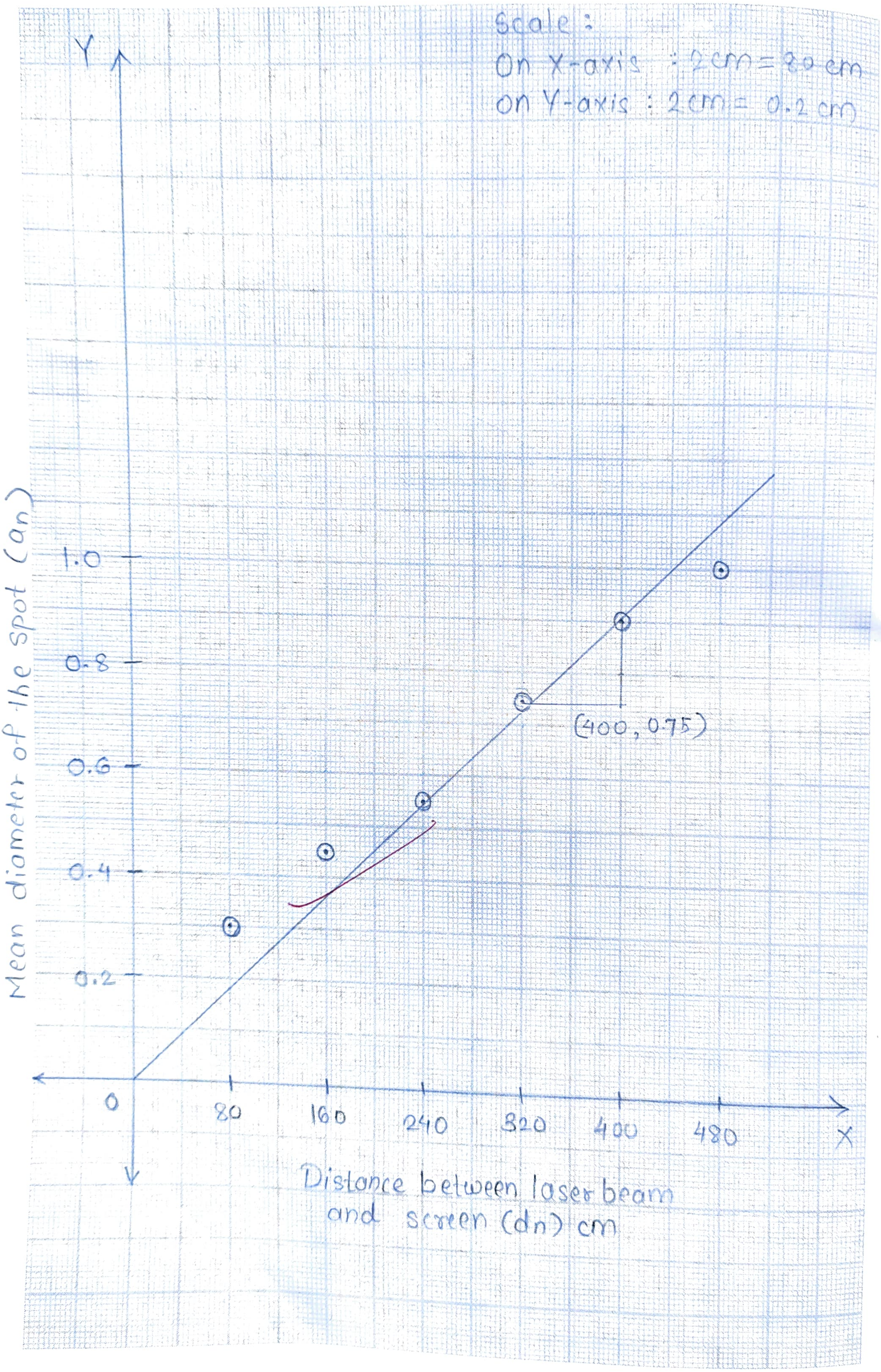
Distance between laser source and the screen (d2) =..........160..........cm

Spot size of the laser beam on the screen for distance d2 (a2)=..........0.45..........cm

Angle of divergence of the laser beam, $\Phi = (a2-a1) / (d2-d1)$ radians

Nature of Graph:




Scale :
On X-axis : 2cm = 80 cm
on Y-axis : 2cm = 0.2 cm
Y
X
Mean diameter of the spot (an)
1.0
0.8
0.6
0.4
0.2
0
80
160
240
320
400
480
(400, 0.75)
Distance between laser beam and screen (dn) cm

Slope :

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\text{Slope} = \frac{0.9 - 0.75}{400 - 320}$$

Slope = 1.875×10^{-3} ~~radians~~.

Results:

1. Angle of divergence of the beam using He-Ne laser by experiment φ =.......1.88×10^{-3}................radians.
2. Angle of divergence of the beam using He-Ne laser by graph (slope) φ =.......1.875×10^{-3}..........radians.

Parameter	C	P	A	Total	Sign. With Date
Marks Obtained	4	3	2	9	[signature] 30.5.23
Max. Marks	4	4	2	10	