MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

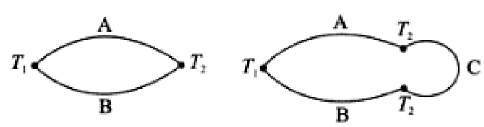
IV SEMESTER B. TECH (MECHANICAL ENGINEERING)
END SEMESTER (GRADE IMPROVEMENT/MAKE-UP) EXAMINATION, AUGUST 2021

SUBJECT: METROGY & MEASUREMENTS (MME 2253)

REVISED CREDIT SYSTEM

Time: 120 Minutes **MAX. MARKS: 40**

Note: Answer ANY FOUR FULL questions.

1A.	An elastic type of pressure-measuring instrument is of diaphragm type. The central deflection of the diaphragm was found to be 0.35 mm of an applied pressure of 10^6 Pa. The output displacement of diaphragm has been fed to an LVDT with a built-in amplifier having a sensitivity of 50 V/mm. Finally, the output is displayed on an analog voltmeter which has a radius of scale line as 80 mm and has a voltage range from zero to 20 volts in an arc of 160°. (i) Draw the generalized block diagram of the pressure measuring instrument to show the functional element in different stages with stating their functions. (ii) Determine the sensitivity of the given diaphragm gauge in terms of mm/bar (1 bar = 10^5 Pa).	**5**
1B.	Differentiate between precision & accuracy. A pressure gauge having a range of 500 kN/m^2 has a guaranteed accuracy of 2% of full scale deflection. What would be the possible readings for a true value of 50 kN/m^2? Estimate the possible readings if the instrument has an error of 2% of the true value.	**5**
2A.	(i) Describe with neat sketch the working of a disappearing filament optical pyrometer (ii) As shown in figure, two thermocouples are used to measure temperature difference (A, B and C are different metals). Will both the arrangements yield the same emf? Justify your answer. 	**5**
2B.	(i) What is the significance of the gauge factor of a strain gauge? (ii) The gauge factor of a resistance wire strain gauge using a soft iron wire of small diameter is 4.2. Neglecting the piezo-resistance effect, calculate the Poisson's ratio. (iii) A strain gauge of 6 micro strain is caused in a structural member when subjected to a compressive force. Two separate strain gauges are attached to the structural member; one is Nickle wire strain gauge (gauge factor = -12.1) & other is Nichrome wire strain gauge (gauge factor = 2). If the resistance of the strain gauges before being strained is 110 Ω, calculate the change in the value of the resistance of the gauges after they are strained.	**5**

3A.	Explain with neat sketch the working of the strain gauge load cell. The following data relate to strain gauge load cell arranged with four identical strain gauges. Diameter of the steel cylinder = 60 mm; Nominal resistance of each gauge = 120 Ω; Gauge factor = 2.0; Supply voltage to the Wheatstone bridge = 6 V; Modulus of elasticity for steel = 200 GN/m^2; Poisson`s ratio = 0.3. Calculate the sensitivity of the load cell.	**5**
3B.	A shaft running at a constant speed of 1500 rpm transmits maximum power of 60 kW. Measurements of torque are made by a pair of strain gauges which are bonded on a specially machined portion of the shaft. Each gauge has a nominal resistance of 100 Ω; gauge factor of 2.0; & are connected electrically to the two half-activated (An equal arm bridge using two active strain gauges) Wheatstone bridge circuit which is energized with an excitation voltage of 6 V. The gauges have a maximum strain of 0.0012. The shear modulus of elasticity of the shaft material is 200 GN/m^2. With the neat sketch show the arrangement of strain gages on rotating shaft & arms of the Wheatstone bridge. Calculate the following: (i) The diameter of the shaft. (ii) The output voltage & sensitivity of the measuring system.	**5**
4A.	Using M112 slip gauge set, list the slip gauges to be wrung together to produce the following dimensions. One protection slip of 2mm size is available and to be used at the top in each case. a) 91.7895mm b) 82.247mm. Also show the setup schematically.	**5**
4B.	Design a plug and ring gauge for the fit $\phi 52 E_7 d_8$. Refer table 1&2 for data.	**5**
5A.	During the straightness measurement of a planar bed using an autocollimator and reflector, the following readings were recorded in minutes. The distance between the legs of the reflector was 120mm. Find the straightness error on the bed. POSITION – Angle (min): A 0.4; B -0.3; C 0.8; D -0.6; E 0.9; F -0.2	**5**
5B.	With the help of neat sketch derive the expression for effective diameter using 2-wire method.	**5**
6A.	Explain with neat sketches the procedure for flatness measurement of a surface table.	**5**
6B.	A M 20 x 2.5 plug screw gauge is checked for effective diameter by a floating carriage micrometer with best size wire and the following readings were noted: Diameter of standard cylinder = 18mm. Micrometer reading over standard cylinder with two wires of same diameter = 14.6420mm. Micrometer reading over the plug screw gauge with two wires of same diameter = 14.2616mm. **a)** Calculate the effective diameter of the gauge **b)** Calculate the effective diameter of the gauge if the standard cylinder diameter is changed to 16mm. **c)** What will be your inference w.r.t both cases?	**5**

Table for 5A:

POSITION	Angle (min)
A	0.4
B	-0.3
C	0.8
D	-0.6
E	0.9
F	-0.2

Table1						
Tolerance Grades	**IT5**	**IT6**	**IT7**	**IT8**	**IT9**	**IT10**
Xi (µm)	**7i**	**10i**	**16i**	**25i**	**40i**	**64i**

Type	**Fundamental Deviation (µm)**
D	**$16D^{0.44}$**
E	**$11D^{0.41}$**
F	**$5.5D^{0.41}$**
G	**$2.5D^{0.34}$**

Table 2

Basic size mm		Standard tolerance grades												
Above	Upto and including	IT1[2)]	IT2[2)]	IT3[2)]	IT4[2)]	IT5[2)]	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13
		Tolerances												
		µm												
-	3[3)]	0.8	1.2	2	3	4	6	10	14	25	40	60	0.1	0.14
3	6	1	1.5	2.5	4	5	8	12	18	30	48	75	0.12	0.18
6	10	1	1.5	2.5	4	6	9	15	22	36	58	90	0.15	0.22
10	18	1.2	2	3	5	8	11	18	27	43	70	110	0.18	0.27
18	30	1.5	2.5	4	6	9	13	21	33	52	84	130	0.21	0.33
30	50	1.5	2.5	4	7	11	16	25	39	62	100	160	0.25	0.39
50	80	2	3	5	8	13	19	30	46	74	120	190	0.30	0.46
80	120	2.5	4	6	10	15	22	35	54	87	140	220	0.35	0.54
120	180	3.5	5	8	12	18	25	40	63	100	160	250	0.4	0.63
180	250	4.5	7	10	14	20	29	46	72	115	185	290	0.46	0.72
250	315	6	8	12	16	23	32	52	81	130	210	320	0.52	0.81

MME 2253: Metrology and Measurements

1. Static Performance Characteristics of Instruments

1.1 Accuracy:

The accuracy may be specified in terms of limit of error

$$\text{\% of true value} = \frac{\text{Measured value} - \text{True value}}{\mathit{True\ value}} * 100$$

$$\text{\% of full scale deflection} = \frac{\text{Measured value} - \text{True value}}{\text{Maximum scale value}} * 100$$

1.2 Sensitivity:

$$\text{Static Sensitivity, K} = \frac{\text{Change of output signal}}{\mathit{Change\ in\ input\ signal}}$$

1.3 Span:

Span of the instrument = Upper scale range – Lower scale range

1.4 Linearity:

$$\text{Non linearity} = \frac{\text{Maximum deviation of output from idealized straight line}}{\text{Full scale deflection}} * 100$$

1.5 Error:

Error = Measured value – True value

2. Pressure Measurement

2.1 The following are the units and conversion factors that are normally used:

- 1 Pa = 1 N/m^2
- 1 atmosphere = 760 mm of Hg
- 1 mm of Hg = 1 Torr
- 1 Torr = 1.316 x 10^{-3} atmosphere = 133.3 Pa
- 1 bar = 10^5 Pa

2.3 The displacement of the bellow due to pressure P is given by,

$$X = 0.453 * P * b * n * D^2\sqrt{(1-\mu^2)} * Et^3$$

Where P = Pressure (N/m^2)
b = radius of each corrugation (m)
n = number of semi-circular corrugations
t = thickness of wall (m)
D= mean diameter (m)
E = modulus of elasticity (N/m^2)
μ = Poisson`s ratio

2.4 The displacement of the diaphragm due to pressure P is given by,

$$Y_{max} = \frac{3}{16} * \frac{P}{Et^3} * R^4(1 - \mu^2)$$

Where P = Pressure N/m^2, R = radius of diaphragm (m), t = diaphragm thickness (m)
E = Young`s modulus of diaphragm materials; N/m$^2$, μ = Poisson`s ratio

2.5 For a McLeod gauge, Unknown Pressure,

$$P_1 = \frac{a*h^2}{V_1}$$

Where, a = Area of cross section of the measuring capillary
h = Height of compressed gas in the measuring capillary
V_1 = Bulb volume including the volume of measuring capillary
= V + (a * h_c)
h_c = Height of measuring capillary tube

2.6 For a Bridgman gauge, Unknown pressure,

$$P = \frac{\frac{dR}{R}}{\frac{2}{E}}$$

Where, R = Resistance of the wire of diameter D and length L

$$= \frac{\rho\, L}{A} = \frac{\rho\, L}{CD^2}$$

ρ = the specific resistance of the material
C = proportionality constant
E = Young's modulus of wire material

2.6.1 Sensitivity = $\frac{\frac{dR}{R}}{P} = \frac{2}{E} = \alpha$

α = Pressure coefficient of resistance of wire material
Bridgeman gauge using manganin element has a pressure coefficient of resistance of 2.3 x 10^{-11} m^2/N

3. Temperature Measurement

3.1 For an Electric resistance thermometer:

Over a limited temperature range around 0 ^{0}C (273 K), the following linear relationship can be applied:

$R_t = R_o (1 + \alpha\, t)$

Where, α = the temperature coefficient of resistance of material in (Ω/Ω)/^{0}C,
R_o = resistance at 0 ^{0}C,
t = temperature relative to 0 ^{0}C.
R_t = resistance at t ^{0}C,

If a change in temperature from t_1 to t_2 is considered, the above equation becomes:

$R_2 = R_1 + R_o\, \alpha\, (t_2 – t_1)$

Rearranging gives: $t_2 = t_1 + [(R_2 – R_1) / \alpha\, R_0]$
Some typical values of α for most commonly used materials are:
Copper = 0.0043 $^0C^{-1}$, Nickel = 0.0068 $^0C^{-1}$, Platinum = 0.0039 $^0C^{-1}$

3.2 For Bimetallic thermometer:

$$R = \frac{t\left[\,3(1+m)^2 + (1+mn) * \left(m^2 + \frac{1}{mn}\right)\right]}{6(\alpha_a - \alpha_b)(T_2 - T_1)(1+m)^2}$$

Where R = Radius of curvature at temperature T_2
t = Total thickness of bimetallic strip = (t_1 + t_2)
m = Thickness of lower expansion metal / Thickness of higher expansion metal
= t_1 / t_2
n = Modulus of elasticity of lower expansion metal / Modulus of elasticity of higher expansion metal
α_H = Coefficient of expansion of higher expansion metal
α_L = Coefficient of expansion of lower expansion metal
T_1 = Initial température
T_2 = Température of the source

4. Strain Measurement

4.1 Electrical Resistance Strain Gauges:

$$\text{Gauge factor, Gf} = \frac{\frac{\Delta \mathrm{R}}{\mathrm{R}}}{\frac{\Delta \mathrm{L}}{L}} = 1 + 2\mu$$

Resistance of unstrained gauge = R = = $\frac{\rho\ \mathrm{L}}{A}$

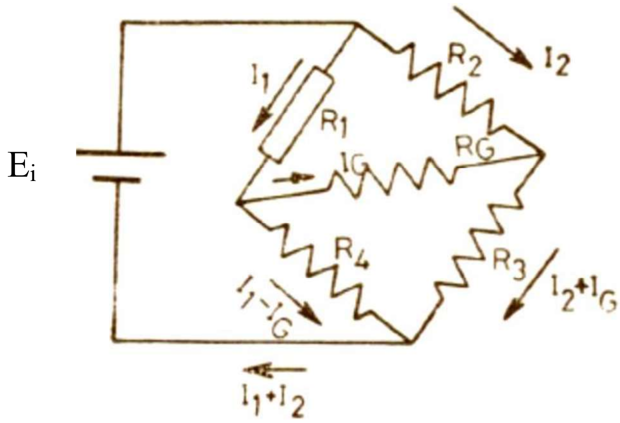
Where, L = Length of the electrical conductor, A = Cross sectional area of the conductor

Poisson's ratio = μ = Lateral strain/Longitudinal strain = - $\frac{\frac{\Delta \mathrm{D}}{\mathrm{D}}}{\frac{\Delta \mathrm{L}}{L}}$

Where, ΔR = change in resistance
ΔL = change in length
ΔD = change in diameter

Grid material	***Gauge Factor***
Nichrome	+ 2.0
Nickel	- 12.0
Platinum	+ 4.8
Manganin	+ 0.47
Isoelastic	+ 3.6
Constantan	+ 2.1
Soft iron	+ 4.2
Carbon	+ 20
Doped Crystals	100 - 5000

4.2 Resistance Strain Gauge Bridge:



The value of unbalanced current I_G can be calculated for any change in strain gauge resistance R_1.

Taking a special case when $R_1 = R_2 = R_3 = R_4$ and if R_1 changes to $R_1 + \Delta R_1$,

$I_G = (- E_i G_f \epsilon_1)/ [4 (R_1 + R_G)]$ where ϵ_1 is the strain which causes ΔR_1, and $\epsilon_1 = \Delta R_1/ R_1 G_f$

If all the four arms have strain gauge whose resistances change due to strains, it can be shown that $I_G = \{(- E_i)/ [4 (R_1 + R_4)]\} [\Delta R_1/R_1 - \Delta R_2/R_2 + \Delta R_3/R_3 - \Delta R_4/R_4]$

4.3 The measuring instrument has an infinitely high internal resistance (for an infinite impedance at output), the change in output-voltage due to applied strain is given by,

$E_0= (- E_i G_f \epsilon_1)/ (4)$ x Signal enhancement factor

4.4 Calibration of strain gauges:

When the gauge factor and gauge resistance are known, the shunting method is used to calibrate strain gauge.

$$\text{Equivalent strain } \epsilon\text{e} = \left(\frac{1}{\mathrm{G_f}}\right) * \left[\frac{R_g}{(R_g+R_{sh})}\right]$$

Where R_g = Strain gauge resistance and R_{sh} = Shunt resistance

Suppose there are `n` active gauges in the Wheatstone bridge,

$$\text{Equivalent strain } \epsilon\text{e} = \left(\frac{1}{\mathrm{G_f}}\right) * \frac{\left[\frac{R_g}{(R_g+R_{sh})}\right]}{n}$$

5. Measurement of Force Torque and Power

5.1 Measurement of Force:

5.1.1 Proving Ring:

$$\mathrm{x} = \frac{\left\{\left[\left(\frac{\pi}{2}\right) - \left(\frac{4}{\pi}\right)\right] * \mathrm{d}^3 * \text{Force}\right\}}{16\ \mathrm{E\ I}}$$

x = The deflection of the ring

d = diameter of the ring

E = modulus of elasticity of ring material

I = moment of inertia

5.1.2 Load Cell:

A tensile compressive load cell uses four strain gauges each mounted at 90^0 to each other on a steel cylinder.

The change in resistance of the strain gauges are measured by the output voltage of the wheat stone bridge is given by,

$$\text{Eo} = \frac{[2(1+\mu) * \text{Gauge factor} * \epsilon * \text{E}]}{4}$$

5.2 Measurement of Torque and Power:

5.2.1 Torque Meter:

In a solid shaft of diameter d, rotating with rpm N, subjected to torque T,

Power = $\frac{2\pi NT}{60}$

Also, Torque, T= $\frac{f_s \pi d^3}{16}$ where f_s = Shear stress induced in the shaft

Shear strain = Shear stress induced in the shaft / Shear modulus

Longitudinal strain in the shaft at 45° to the axis of the shaft, ϵ_{45} = Shear strain / 2

ϵ_{45} may be measured by resistance strain gauge.

5.2.2 Cradled Dynamometer:

If F is the force at the support, the torque T transmitted by the dynamometer is given by T= F * L.
Thus by measuring the force F, the transmitted torque is measured.
The power transmitted can be calculated from the torque, using the equation

P = ω * T

Where P is the power (W), T the torque (N-m) and ω the angular speed (rad /s)

5.2.3 Rope Brake Dynamometer:

One end of the rope is connected to a mass while the other end is connected to a spring balance is wound on a pulley with radius r.

If s is the force in the spring balance, torque T = (W – S) * r

r being the pulley radius, W = m * g

The power is, P= $\frac{2\pi N(W-S) * r}{60}$ where N is the speed in rpm

6. Flow Measurement

6.1 Orifice meter:

Flow rate is given by,

$$Q = C_d \times \frac{A_2}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}} \times \sqrt{\frac{2(P_1-P_2)}{\rho}}$$

Where, C_d = Coefficient of discharge, ρ = density of the flowing fluid,
P_1 and P_2 refer to the pressure values at the normal flow and vena contracta positions, respectively;
A_1 = Cross section area of the pipe, A_2 = Cross section area of the orifice plate

6.2 Pitot tube:

Flow velocity is given by,

$$v = \sqrt{\frac{2}{\rho} \times (P_2 - P_1)}$$

Where, ρ = density of the flowing fluid
P_2 = stagnation or total pressure of the free stream given by the stagnation tube
P_1 = Free stream static pressure given by static tube

6.3 Rotameter:

Flow rate is given by,

$$Q = C_d \left[\frac{A_t(A_t-A_f)}{\sqrt{(A_t)^2-(A_t-A_f)^2}}\right] * \sqrt{2g} * \sqrt{\frac{P_d-P_u}{\rho_{ff} * g}}$$

Where, C_d = Coefficient of discharge
ρ_f and ρ_{ff} are the densities of the float and floating fluid, respectively
V_f is the volume of the float
P_d and P_u are the pressure at the downward and upward faces of the float, respectively

$$Q = C_d \left[\frac{(A_t-A_f)}{\sqrt{1-\frac{(A_t-A_f)^2}{(A_t)^2}}}\right] * \sqrt{2g} * \sqrt{\frac{V_f}{A_f}} * \sqrt{\frac{\rho_f-\rho_{ff}}{\rho_{ff}}}$$

Where, A_t is the area of the tube at the float level,
($A_t - A_f$) is the minimum annular area between tube and the float

7. Limits, Fits and Tolerances

7.1 Standard Tolerance Unit (i) in Micron:

$$i = 0.45\sqrt[3]{D} + 0.001D$$

where, D – Diameter in mm: $D = \sqrt{Di \times Df}$

Di – Initial value of Standard Diameter range in mm

Df – Final value of Standard Diameter range in mm

The various standard diameter main ranges specified by I.S.I, are: 1—3, 3—6, 6—10, 10—18, 18—30, 30—50, 50—80, 80—120, 120—180, 180—250, 250—315, 315-400, 400—500, 500—630, 630—800, 800—1000, 1000—1250, 1250—1600, 1600—2000, 2000—2500, 2500—3150 mm

Table 7.1: International Tolerance Grades

Tolerance Grade	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
Magnitude	7i	10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i

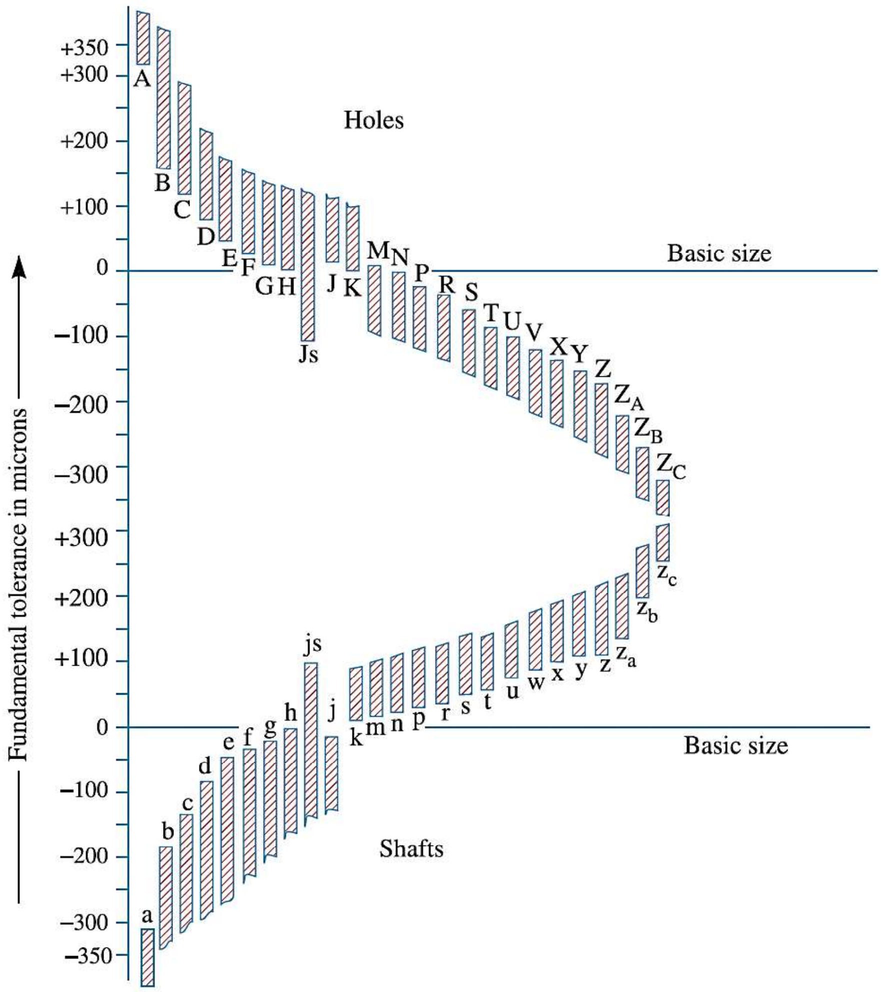


Figure 7.1: Fundamental deviation chart and Formula

7.2 Fits:

- **Clearance fit**:
  Maximum clearance = UL of hole – LL of shaft
  Minimum clearance = LL of hole – UL of shaft

- **Interference fit**:
  Maximum interference = LL of hole – UL of shaft
  Minimum interference = UL of hole – LL of shaft

- **Transition fit**:
  Maximum clearance = UL of hole – LL of shaft
  Maximum interference = LL of hole – UL of shaft
  Here, UL is the Upper limit size & LL is the Lower limit size

Table 7.2: Formulae for deviation for shafts and holes

Shaft			Holes			Formulae for deviation in micron
Shaft designation	Fundamental deviation	Sign	Hole designation	Fundamental deviation	Sign	For "d" in mm
d	es	-	D	EI	+	$16D^{0.44}$
e	es	-	E	EI	+	$11D^{0.41}$
f	es	-	F	EI	+	$5.5D^{0.41}$
g	es	-	G	EI	+	$2.5D^{0.34}$
h	es	No Sign	H	EI	No Sign	0
js	ei	-	JS	ES	+	0.5ITn
k	ei	+	K	ES	-	0
m	ei	+	M	ES	-	0.024D+12.6
n	ei	+	N	ES	-	0.04+21
p	ei	+	P	ES	-	0.072D+37.8
r	ei	+	R	ES	-	Geometric mean of the values "p" and "s" or "P" and "S"
s	ei	+	S	ES	-	IT7+0.4D
t	ei	+	T	ES	-	IT7+0.63D
u	ei	+	U	ES	-	IT7+D

8. Gauges

Gauge Makers Tolerance (GMT):

$$\text{GMT} = \frac{1}{10} \text{ X Work Tolerence}$$

$$\text{Wear Allowance} = \frac{1}{10} \text{ X GMT}$$

Table 8.1: Slip gauges – M112 Set

Range (mm)	Step (mm)	No. of Pieces
1.001 to 1.009	0.001	09
1.010 to 1.490	0.010	49
0.50 to 24.50	0.500	49
25, 50, 55, 100	25	04
1.0005	-	01
Total		112

9. Measurement of Form Errors

Table 9.1: Determination of straightness using an autocollimator

Position	Mean reading of auto-collimator (sec)	Difference from first reading (sec)	Rise or fall interval length 'l" (mm)	Cumulative rise or fall (mm)	Adjustment to bring both ends to zero (mm)	Errors from straight line (mm)
1	2	3	4	5	6	7
a				0	0	0
a – b	θ_1	$\theta_1 - \theta_1 = 0$	0	0	- L/n	- L/n
b – c	θ_2	$\theta_2 - \theta_1$	$(\theta_2 - \theta_1)\times l$	$(\theta_2 - \theta_1)\times l$	- 2L/n	$(\theta_2 - \theta_1)\times l$ - 2L/n
c – d	θ_3	$\theta_3 - \theta_1$	$(\theta_3 - \theta_1)\times l$	$(\theta_2 - \theta_1)\times l + (\theta_3 - \theta_1)\times l$	-3L/n	$(\theta_2 - \theta_1)\times l + (\theta_3 - \theta_1)\times l$ - 3L/n
e – f	θ_4	$\theta_4 - \theta_1$	$(\theta_4 - \theta_1)\times l$	$(\theta_2 - \theta_1)\times l + (\theta_3 - \theta_1)\times l + (\theta_4 - \theta_1)\times l$		
f – g						
g – h						
h – i	θ_n	$\theta_n - \theta_1$	$(\theta_n - \theta_1)\times l$	$\Sigma\ (\theta_n - \theta_1)\times l = L$	- L	0

$$1 \text{ minute of arc} = \frac{2\pi}{360\times 60} \text{ radians}$$

10. Surface Texture Measurement

10.1 Center Line Average Height (R_a)

$$R_a = \frac{1}{n}(h_1 + h_2 + h_3 \ldots\ldots\ldots\ldots\ldots\ldots + h_n)$$

where, h_1, h_2, h_3,…….. h_n are the heights measured at various points.

n = number of points

10.2 Root Mean Square Value (RMS)

$$RMS = \sqrt{\frac{(h_1^2 + h_2^2 + h_3^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots h_n^2)}{n}}$$

where, h_1, h_2, h_3,…….. h_n are the heights measured at various points.

n = number of points.

10.3 Ten-point Height Average Value (R_z)

$$R_z = \frac{(h_1 + h_3 + h_5 + h_7 + h_9) - (h_2 + h_4 + h_6 + h_8 + h_{10})}{5}$$

where, h_1, h_3, h_5, h_7 & h_9 are the five highest peaks.

h_2, h_4, h_6, h_8 & h_{10} are the five deepest valleys

10.4 CLA (if area is given), then R_a is

$$\frac{Sum\ of\ areas(mm^2)}{Sampling\ length\ (mm)} \times \frac{1000}{Vertical\ magnification} \times \frac{1}{Horizontal\ magnification}$$

11. Measurement of Screw Threads

11.1 Two Wire Method:

Effective diameter, E = T + P

T = Dimension under the wires (mm)

P = Correction factor

T = M - 2d

d = Diameter of the best-size wire (mm)

M = Dimension over the wires (mm)

$$\mathrm{P} = \left[\frac{\mathrm{p}}{2}\ \mathrm{Cot}\frac{\theta}{2}\right] - \mathrm{d}\left[\mathrm{Cosec}\frac{\theta}{2} - 1\right]$$

p = Pitch of thread (mm)

θ = Angle of thread

11.2 Three-wire method:

Effective Diameter

$$\mathrm{E} = \mathrm{M} - \mathrm{d}\left[1 + \mathrm{Cosec}\frac{\theta}{2}\right] + \left[\frac{\mathrm{p}}{2}\ \mathrm{Cot}\frac{\theta}{2}\right]$$

M = Dimension over the wires (mm)

p = Pitch of thread (mm)

θ = Angle of thread

11.3 Diameter of Best-size wire:

$$\mathrm{d_b} = 2\left[\frac{\mathrm{p}}{4}\right]\ \mathrm{Sec}\,\theta$$

p = Pitch of thread (mm)

θ = Angle of thread