Materials and Mechanics Practice (MANUAL) PHY109P
B. Tech: July---November 2016

IIITD&M Kancheepuram
Chennai – 600 127

CYCLE – I (LIST OF EXPERIMENTS)

1. TORSIONAL PENDULUM
2. BAR PENDULUM
3. STRAIN GAUGE
4. TENSILE TEST
5. FRICTION

CYCLE – II

6. CREEP TEST
7. THREE POINT BEND TEST
8. BUCKLING TEST
9. MICROSTRUCTURE
10. HARDNESS TEST AND TORQUE MEASUREMNET

EXPT NO / WEEK	1	2	3	4	5
I	**BL_1 1 – BL_1 5 BL_2 1 – BL_2 5 BL_3 1 – BL_3 5 BL_4 1 – BL_4 5 BL_5 1 – BL_5 5 KL_1 1 – KL_1 5 KL_2 1 – KL_2 5**	**BL_1 6 – BL_1 10 BL_2 6 – BL_2 10 BL_3 6 – BL_3 10 BL_4 6 – BL_4 10 BL_5 6 – BL_5 10 KL_1 6 – KL_1 10 KL_2 6 – KL_2 10**	**BL_1 11 – BL_1 15 BL_2 11 – BL_2 15 BL_3 11 – BL_3 15 BL_4 11 – BL_4 15 BL_5 11 – BL_5 15 KL_1 11 – KL_1 15 KL_2 11 – KL_2 15**	**BL_1 16 – BL_1 20 BL_2 16 – BL_2 20 BL_3 16 – BL_3 20 BL_4 16 – BL_4 20 BL_5 16 – BL_5 20 KL_1 16 – KL_1 20 KL_2 16 – KL_2 20**	**BL_1 21 – BL_1 25 BL_2 21 – BL_2 25 BL_3 21 – BL_3 25 BL_4 21 – BL_4 25 BL_5 21 – BL_5 25 KL_1 21 – KL_1 25 KL_2 21 – KL_2 25**
II	**BL_1 21 – BL_1 25 BL_2 21 – BL_2 25 BL_3 21 – BL_3 25 BL_4 21 – BL_4 25 BL_5 21 – BL_5 25 KL_1 21 – KL_1 25 KL_2 21 – KL_2 25**	**BL_1 1 – BL_1 5 BL_2 1 – BL_2 5 BL_3 1 – BL_3 5 BL_4 1 – BL_4 5 BL_5 1 – BL_5 5 KL_1 1 – KL_1 5 KL_2 1 – KL_2 5**	**BL_1 6 – BL_1 10 BL_2 6 – BL_2 10 BL_3 6 – BL_3 10 BL_4 6 – BL_4 10 BL_5 6 – BL_5 10 KL_1 6 – KL_1 10 KL_2 6 – KL_2 10**	**BL_1 11 – BL_1 15 BL_2 11 – BL_2 15 BL_3 11 – BL_3 15 BL_4 11 – BL_4 15 BL_5 11 – BL_5 15 KL_1 11 – KL_1 15 KL_2 11 – KL_2 15**	**BL_1 16 – BL_1 20 BL_2 16 – BL_2 20 BL_3 16 – BL_3 20 BL_4 16 – BL_4 20 BL_5 16 – BL_5 20 KL_1 16 – KL_1 20 KL_2 16 – KL_2 20**
III	**BL_1 16 – BL_1 20 BL_2 16 – BL_2 20 BL_3 16 – BL_3 20 BL_4 16 – BL_4 20 BL_5 16 – BL_5 20 KL_1 16 – KL_1 20 KL_2 16 – KL_2 20**	**BL_1 21 – BL_1 25 BL_2 21 – BL_2 25 BL_3 21 – BL_3 25 BL_4 21 – BL_4 25 BL_5 21 – BL_5 25 KL_1 21 – KL_1 25 KL_2 21 – KL_2 25**	**BL_1 1 – BL_1 5 BL_2 1 – BL_2 5 BL_3 1 – BL_3 5 BL_4 1 – BL_4 5 BL_5 1 – BL_5 5 KL_1 1 – KL_1 5 KL_2 1 – KL_2 5**	**BL_1 6 – BL_1 10 BL_2 6 – BL_2 10 BL_3 6 – BL_3 10 BL_4 6 – BL_4 10 BL_5 6 – BL_5 10 KL_1 6 – KL_1 10 KL_2 6 – KL_2 10**	**BL_1 11 – BL_1 15 BL_2 11 – BL_2 15 BL_3 11 – BL_3 15 BL_4 11 – BL_4 15 BL_5 11 – BL_5 15 KL_1 11 – KL_1 15 KL_2 11 – KL_2 15**
IV	**BL_1 11 – BL_1 15 BL_2 11 – BL_2 15 BL_3 11 – BL_3 15 BL_4 11 – BL_4 15 BL_5 11 – BL_5 15 KL_1 11 – KL_1 15 KL_2 11 – KL_2 15**	**BL_1 16 – BL_1 20 BL_2 16 – BL_2 20 BL_3 16 – BL_3 20 BL_4 16 – BL_4 20 BL_5 16 – BL_5 20 KL_1 16 – KL_1 20 KL_2 16 – KL_2 20**	**BL_1 21 – BL_1 25 BL_2 21 – BL_2 25 BL_3 21 – BL_3 25 BL_4 21 – BL_4 25 BL_5 21 – BL_5 25 KL_1 21 – KL_1 25 KL_2 21 – KL_2 25**	**BL_1 1 – BL_1 5 BL_2 1 – BL_2 5 BL_3 1 – BL_3 5 BL_4 1 – BL_4 5 BL_5 1 – BL_5 5 KL_1 1 – KL_1 5 KL_2 1 – KL_2 5**	**BL_1 6 – BL_1 10 BL_2 6 – BL_2 10 BL_3 6 – BL_3 10 BL_4 6 – BL_4 10 BL_5 6 – BL_5 10 KL_1 6 – KL_1 10 KL_2 6 – KL_2 10**
V	**BL_1 6 – BL_1 10 BL_2 6 – BL_2 10 BL_3 6 – BL_3 10 BL_4 6 – BL_4 10 BL_5 6 – BL_5 10 KL_1 6 – KL_1 10 KL_2 6 – KL_2 10**	**BL_1 11 – BL_1 15 BL_2 11 – BL_2 15 BL_3 11 – BL_3 15 BL_4 11 – BL_4 15 BL_5 11 – BL_5 15 KL_1 11 – KL_1 15 KL_2 11 – KL_2 15**	**BL_1 16 – BL_1 20 BL_2 16 – BL_2 20 BL_3 16 – BL_3 20 BL_4 16 – BL_4 20 BL_5 16 – BL_5 20 KL_1 16 – KL_1 20 KL_2 16 – KL_2 20**	**BL_1 21 – BL_1 25 BL_2 21 – BL_2 25 BL_3 21 – BL_3 25 BL_4 21 – BL_4 25 BL_5 21 – BL_5 25 KL_1 21 – KL_1 25 KL_2 21 – KL_2 25**	**BL_1 1 – BL_1 5 BL_2 1 – BL_2 5 BL_3 1 – BL_3 5 BL_4 1 – BL_4 5 BL_5 1 – BL_5 5 KL_1 1 – KL_1 5 KL_2 1 – KL_2 5**

- Batches BL_1, BL_2, BL_3, BL_4, BL_5 are – IIITDM Kancheepuram

** Batches KL_1, KL_2 are – IIITDM Kurnool

IIITDM KANCHEEPURAM – BATCH BL1

S.No	Roll No.	Group No.	Day	S.No	Roll No.	Group No.
1	COE16B001	**BL_1 – 1**	**MONDAY (AN)**	21	COE16B023	**BL_1 – 14**
2	COE16B002			22	COE16B024	**BL_1 – 15**
3	COE16B003	**BL_1 – 2**		23	COE16B025	
4	COE16B004	**BL_1 – 3**		24	COE16B026	**BL_1 – 16**
5	COE16B005			25	COE16B027	**BL_1 – 17**
6	COE16B006	**BL_1 – 4**		26	COE16B028	
7	COE16B007	**BL_1 – 5**		27	COE16B029	**BL_1 – 18**
8	COE16B008			28	COE16B030	**BL_1 – 19**
9	COE16B011	**BL_1 – 6**		29	COE16B031	
10	COE16B012	**BL_1 – 7**		30	COE16B032	**BL_1 – 20**
11	COE16B013			31	COE16B033	**BL_1 – 21**
12	COE16B014	**BL_1 – 8**		32	COE16B034	
13	COE16B015	**BL_1 – 9**		33	COE16B035	**BL_1 – 22**
14	COE16B016			34	COE16B036	**BL_1 – 23**
16	COE16B017	**BL_1 – 10**		35	COE16B037	
16	COE16B018	**BL_1 – 11**		36	COE16B038	**BL_1 – 24**
17	COE16B019			37	COE16B039	**BL_1 – 25**
18	COE16B020	**BL_1 – 12**		38	COE16B040	
19	COE16B021	**BL_1 – 13**		39		
20	COE16B022			40		

IIITDM KANCHEEPURAM – BATCH BL5

S.No	Roll No.	Group No.	Day	S.No	Roll No.	Group No.
1	MSM16B001	BL_5 – 1	TUESDAY (AN)	26	MSM16B028	BL_5 – 13
2	MSM16B002			27	MSM16B029	BL_5 – 14
3	MSM16B003	BL_5 – 2		28	MSM16B030	
4	MSM16B005			29	MSM16B031	BL_5 – 15
5	MSM16B006	BL_5 – 3		30	MSM16B032	
6	MSM16B007			31	MSM16B034	BL_5 – 16
7	MSM16B008	BL_5 – 4		32	MSM16B035	
8	MSM16B009			33	MSM16B036	BL_5 – 17
9	MSM16B010	BL_5 – 5		34	MFD16I001	
10	MSM16B011			35	MFD16I002	BL_5 – 18
11	MSM16B012	BL_5 – 6		36	MFD16I003	
12	MSM16B013			37	MFD16I004	BL_5 – 19
13	MSM16B014	BL_5 – 7		38	MFD16I005	
14	MSM16B015			39	MFD16I006	BL_5 – 20
16	MSM16B016	BL_5 – 8		40	MFD16I007	
16	MSM16B017			41	MFD16I008	BL_5 – 21
17	MSM16B018	BL_5 – 9		42	MFD16I010	
18	MSM16B019			43	MFD16I011	BL_5 – 22
19	MSM16B020	BL_5 – 10		44	MFD16I012	
20	MSM16B021			45	MFD16I014	BL_5 – 23
21	MSM16B022	BL_5 – 11		46	MFD16I015	
22	MSM16B024			47	MFD16I016	BL_5 – 24
23	MSM16B025	BL_5 – 12		48	MFD16I017	
24	MSM16B026			49	MFD16I018	BL_5 – 25
25	MSM16B027	BL_5 – 13		50	MFD16I019	

IIITDM KANCHEEPURAM – BATCH BL4

S.No	Roll No.	Group No.	Day	S.No	Roll No.	Group No.
1	MDM16B001	BL_4 – 1	WEDNESDAY (FN)	27	MDM16B028	BL_4 – 13
2	MDM16B002			28	MDM16B029	BL_4 – 14
3	MDM16B003	BL_4 – 2		29	MDM16B030	
4	MDM16B004			30	MDM16B031	BL_4 – 15
5	MDM16B005	BL_4 – 3		31	MDM16B032	
6	MDM16B006			32	MDM16B033	BL_4 – 16
7	MDM16B007	BL_4 – 4		33	MDM16B034	
8	MDM16B008			34	MDM16B035	BL_4 – 17
9	MDM16B009	BL_4 – 5		35	MDM16B036	
10	MDM16B010			36	MDM16B037	BL_4 – 18
11	MDM16B011	BL_4 – 6		37	MDM16B038	
12	MDM16B012			38	MDM16B039	BL_4 – 19
13	MDM16B013	BL_4 – 7		39	MDM16B040	
14	MDM16B014			40	MPD16I001	BL_4 – 20
16	MDM16B015	BL_4 – 8		41	MPD16I002	
16	MDM16B016			42	MPD16I003	BL_4 – 21
17	MDM16B017	BL_4 – 9		43	MPD16I004	
18	MDM16B018			44	MPD16I005	BL_4 – 22
19	MDM16B019	BL_4– 10		45	MPD16I006	
20	MDM16B020			46	MPD16I007	BL_4 – 23
21	MDM16B021	BL_4– 11		47	MPD16I009	
22	MDM16B022			48	MPD16I010	BL_4 – 24
23	MDM16B024	BL_4– 12		49	MPD16I011	
24	MDM16B025			50	MPD16I012	BL_4 – 25
25	MDM16B026	BL_4 – 13		51	MPD16I014	
26	MDM16B027			52	MPD16I015	

IIITDM KANCHEEPURAM – BATCH BL3

S.No	Roll No.	Group No.	Day	S.No	Roll No.	Group No.
1	EDM16B001	BL_3 – 1	WEDNESDAY (AN)	27	EDM16B027	BL_3 – 13
2	EDM16B002			28	EDM16B028	BL_3 – 14
3	EDM16B003	BL_3 – 2		29	EDM16B029	
4	EDM16B004			30	EDM16B030	BL_3 – 15
5	EDM16B005	BL_3 – 3		31	EDM16B031	
6	EDM16B006			32	EDM16B032	BL_3 – 16
7	EDM16B007	BL_3 – 4		33	EDM16B033	
8	EDM16B008			34	EDM16B034	BL_3 – 17
9	EDM16B009	BL_3 – 5		35	EDM16B035	
10	EDM16B010			36	EDM16B036	BL_3 – 18
11	EDM16B011	BL_3 – 6		37	EDM16B038	
12	EDM16B012			38	EDM16B039	BL_3 – 19
13	EDM16B013	BL_3 – 7		39	ESD16I001	
14	EDM16B014			40	ESD16I003	BL_3 – 20
16	EDM16B015	BL_3 – 8		41	ESD16I004	
16	EDM16B016			42	ESD16I005	BL_3 – 21
17	EDM16B017	BL_3 – 9		43	ESD16I006	
18	EDM16B018			44	ESD16I007	BL_3 – 22
19	EDM16B019	BL_3– 10		45	ESD16I008	
20	EDM16B020			46	ESD16I009	BL_3 – 23
21	EDM16B021	BL_3– 11		47	ESD16I011	
22	EDM16B022			48	ESD16I012	BL_3 – 24
23	EDM16B023	BL_3– 12		49	ESD16I013	
24	EDM16B024			50	ESD16I014	BL_3 – 25
25	EDM16B025	BL_3– 13		51	ESD16I015	
26	EDM16B026			52		

IIITDM KANCHEEPURAM – BATCH BL2

S.No	Roll No	Group No.	Day	S.No	Roll No	Group No.
1	CED16I002	BL_2 – 1	THURSDAY(AN)	30	CED16I031	BL_2 – 13
2	CED16I003			31	CED16I032	BL_2 – 14
3	CED16I004	BL_2 – 2		32	CED16I033	
4	CED16I005			33	CED16I034	
5	CED16I006			34	CED16I035	BL_2 – 15
6	CED16I007	BL_2 – 3		35	CED16I036	
7	CED16I008			36	CED16I037	BL_2 – 16
8	CED16I009	BL_2 – 4		37	CED16I038	
9	CED16I010			38	CED16I039	BL_2 – 17
10	CED16I011			39	CED16I041	
11	CED16I012	BL_2 – 5		40	CED16I042	BL_2 – 18
12	CED16I013			41	EVD16I001	
13	CED16I014	BL_2 – 6		42	EVD16I002	
14	CED16I015			43	EVD16I003	BL_2 – 19
16	CED16I016	BL_2 – 7		44	EVD16I004	
16	CED16I017			45	EVD16I005	BL_2 – 20
17	CED16I018	BL_2 – 8		46	EVD16I006	
18	CED16I019			47	EVD16I007	BL_2 – 21
19	CED16I020			48	EVD16I008	
20	CED16I021	BL_2 – 9		49	EVD16I009	BL_2 – 22
21	CED16I022			50	EVD16I010	
22	CED16I023	BL_2 – 10		51	EVD16I011	
23	CED16I024			52	EVD16I012	BL_2 – 23
24	CED16I025	BL_2 – 11		53	EVD16I013	
25	CED16I026			54	EVD16I014	BL_2 – 24
26	CED16I027	BL_2 – 12		55	EVD16I015	
27	CED16I028			56	EVD16I016	
28	CED16I029			57	EVD16I017	BL_2 – 25
29	CED16I030	BL_2 – 13		58	EVD16I018	

IIITDM KURNOOL – BATCH 1

S.No	Roll No.	Group No.	Day	S.No	Roll No.	Group No.
1	COE16B001	KL_1 – 1	MONDAY (FN)		COE16B026	KL_1 – 13
2	COE16B002			26	COE16B027	KL_1 – 14
3	COE16B003	KL_1 – 2		27	COE16B028	
4	COE16B004			28	COE16B029	KL_1 – 15
5	COE16B005	KL_1 – 3		29	COE16B030	
6	COE16B006			30	COE16B031	KL_1 – 16
7	COE16B007	KL_1 – 4		31	COE16B032	
8	COE16B008			32	COE16B033	KL_1 – 17
9	COE16B009	KL_1 – 5		33	EDM16B001	
10	COE16B010			34	EDM16B002	KL_1 – 18
11	COE16B011	KL_1 – 6		35	EDM16B003	
12	COE16B012			36	EDM16B004	KL_1 – 19
13	COE16B013	KL_1 – 7		37	EDM16B006	
14	COE16B014			38	EDM16B008	KL_1– 20
16	COE16B016	KL_1 – 8		39	EDM16B009	KL_1 – 21
16	COE16B017			40	EDM16B010	
17	COE16B018	KL_1 – 9		41	EDM16B011	KL_1 – 22
18	COE16B019			42	EDM16B012	
19	COE16B020	KL_1– 10		43	EDM16B013	KL_1 – 23
20	COE16B021	KL_1 – 11		44	EDM16B014	
21	COE16B022			45	EDM16B015	KL_1 – 24
22	COE16B023	KL_1 – 12		46	EDM16B016	
23	COE16B024			47	EDM16B017	KL_1 – 25
24	COE16B025	KL_1 – 13		48	EDM16B018	

IIITDM KURNOOL – BATCH 2

S.No	Roll No.	Group No.	Day	S.No	Roll No.	Group No.
1	EDM16B021	**KL_2 – 1**	**FRIDAY (AN)**	14	MDM16B008	**KL_2 – 14**
2	EDM16B022	**KL_2 – 2**		15	MDM16B009	**KL_2 – 15**
3	EDM16B024	**KL_2 – 3**		16	MDM16B010	**KL_2 – 16**
4	EDM16B025	**KL_2 – 4**		17	MDM16B011	**KL_2 – 17**
5		**KL_2 – 5**		18	MDM16B012	**KL_2 – 18**
6	MDM16B001	**KL_2 – 6**		19	MDM16B013	**KL_2 – 19**
7	MDM16B002	**KL_2 – 7**		20	MDM16B014	**KL_2 – 20**
8	MDM16B003	**KL_2 – 8**		21		**KL_2 – 21**
9	MDM16B004	**KL_2 – 9**		22	MDM16B015	**KL_2 – 22**
10	MDM16B005	**KL_2 – 10**		23	MDM16B016	**KL_2 – 23**
11		**KL_2 – 11**		24	MDM16B018	**KL_2 – 24**
12	MDM16B006	**KL_2 – 12**		25	MDM16B021	**KL_2 – 25**
13	MDM16B007	**KL_2 – 13**		26		

EX. NO.1: TORSIONAL PENDULUM

OBJECTIVE:

To find the modulus of rigidity (η) and torsional rigidity (C) of the given string.

APPARATUS REQUIRED:

Circular or rectangular discs suspended from a point using a metal wire about an axis passing through the middle of plate having largest area, two similar weights, a stop watch and meter scale.

BRIEF DISCUSSION AND RELEVANT FORMULA:

For an object under torsion torsional, restoring torque is proportional to the angular displacements. In practice, this will be true only for **small** angular displacements 'θ'.

$$\tau = I_{tot}\, d^2\theta/dt^2 = -C\,\theta \qquad (1)$$

The equation gives the time period of torsional oscillations of the system as,

$$T = 2\pi\sqrt{\frac{I_{tot}}{C}} = 2\pi\sqrt{\frac{I_o + 2\,I_s + 2\,m_s\,x^2}{C}} \qquad (2)$$

I_o = moment of inertia of large disc (without any mass added to it)
I_s = moment of inertia of weight - about an axis passing through its/their own center of gravity, parallel to its/their length.
m_s = mass of each solid cylinder (weight)
x = distance of each weight from axis of suspension.
C = torsional rigidity of suspension wire - (couple per unit twist).

Fig.1

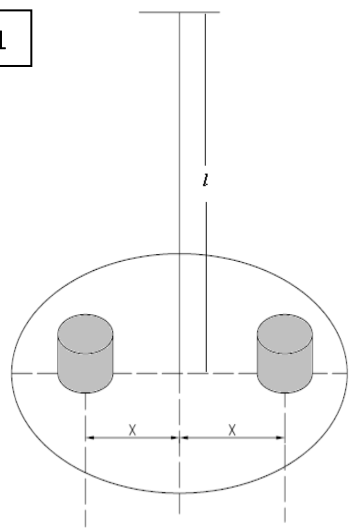
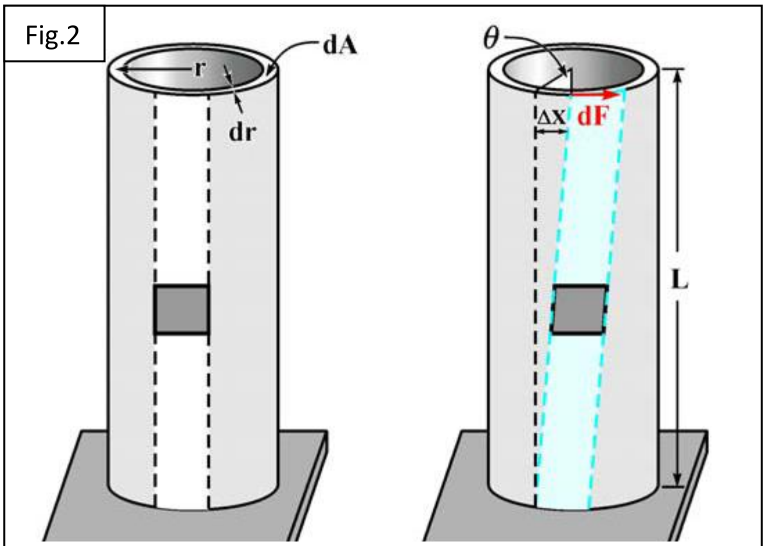


Fig.2



Again from Fig.2, rigidity modulus $\eta = \frac{\left(dF / \pi r^2 \right)}{\left(r\theta / L \right)} = \frac{l(rdF)}{\pi r^4 \theta} = \frac{l\tau}{\pi r^4 \theta}$ (3)

We can write the magnitude of ***C*** from (1) and (3), $C = \frac{\pi \, \eta \, r^4}{2 \, l}$ (4)

Squaring (2), we get

$$T^2 = \frac{4\pi^2}{C}[I_o + 2I_s + 2\, m_s x^2] = \frac{8\pi^2 m_s x^2}{C} + \frac{4\,\pi^2\,(I_o + 2I_s)}{C} \quad (5)$$

A graph is plotted between T^2 and x^2. Fit a best - fit straight line to the data.

For the straight line, $slope = \frac{\Delta T^2}{\Delta\, x^2} = \frac{8\pi^2 m_s}{C}$ or $C = 8\pi^2 m_s \frac{\Delta\, x^2}{\Delta T^2}$ (6)

Knowing, C from (6) one can calculate the rigidity modulus (η) from (4).

Note that :

- The suspension wire should be free from kinks.
- The system should be horizontal always.
- Solid weights must be identical.
- Oscillations should be purely rotational.
- The wire should not be twisted beyond elastic limits.
- The time period should be noted carefully taking the average of about ten periods.
- Make sure that the angular displacements are small.

The student must then compute,

Couple per unit twist of suspension wire C

Determination of I_s and I_o:: I_s and I_o can be obtained by measuring corresponding time periods as mentioned below.

Let T_o = time period of oscillation of large disc alone.

T_x = time period of oscillations of large disc with masses at distance *x*.

T_{x0} = time period of oscillation of large disc with masses at *x* =0,(obtained from graph – y intercept).

Putting these time periods in (5) , we will get a set of equations which will give us the following expressions:

$$I_0 = 2m_s x^2 \frac{T_0^2}{T_x^2 - T_{x0}^2} = \frac{2m_s T_0^2}{slope}$$

$$I_s = m_s x^2 \frac{T_{x0}^2 - T_0^2}{T_x^2 - T_{x0}^2} = \frac{m_s (T_{x0}^2 - T_0^2)}{slope}$$

OBSERVATIONS:

Mass of identical weights added, m_s = ……………. kg

Time period of disc with no masses T_o = ……………….sec (averaged over 10 cycles)

Y-intercept from graph T_{xo} = ………………sec

TABLE: MEASURE THE TIME PERIOD

Distance of weight from axis of twist *x* (cm)	x^2 (cm^2)	Number of oscillations, *n*	Time taken *t* (sec)	Period *T= t / n* (sec)	T^2 (sec^2)
x_1					
x_2					
x_3					
x_4					

RESULT: **1.** Rigidity modulus of the wire, η=

2. Couple per unit twist, C=

3. Moment of Inertia of the disc, I_o=

EX.NO. 2: BAR PENDULUM

OBJECTIVE:

1. To determine the acceleration due to gravity (*g*) using a bar pendulum.
2. To verify that there are two pivot points on either side of the centre of gravity (C.G.) about which the time period is the same.
3. To determine the radius of gyration of a bar pendulum by plotting a graph of time period of oscillation against the distance of the point of suspension from C.G.
4. To determine the length of the equivalent simple pendulum.

APPARATUS REQUIRED:

Bar Pendulum, Small metal wedge, Spirit level, Stop watch, Meter rod

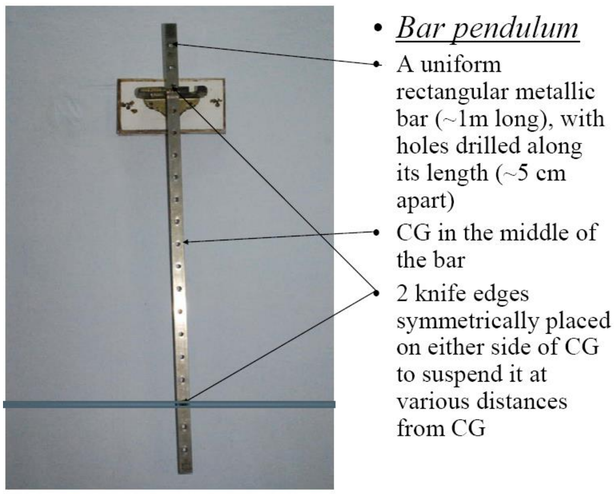
THEORY:

A bar pendulum is the simplest form of compound pendulum. It is in the form of a rectangular bar (with its length much larger than the breadth and the thickness) with holes (for fixing the knife edges) drilled along its length at equal separation.

If a bar pendulum of mass *M* oscillates with a very small amplitude ϑ about a horizontal axis passing through it, then its angular acceleration ($d^2\vartheta/dt^2$) is proportional to the angular displacement ϑ. The motion is **simple harmonic** and the time period *T* is given by

$$T = 2\pi\sqrt{\frac{I}{Mgl}} \qquad (1)$$

where *I* denotes the **moment of inertia** of the pendulum about the horizontal axis through its **center of suspension** and *l* is the distance between the center of suspension and C.G. of the



Photograph of a typical bar pendulum

Pendulum. According to the theorem of parallel axes, if I_G is the moment of inertia of the pendulum about an axis through C.G., then the moment of inertia I about a parallel axis at a distance l from C.G. is given by

$$I = I_G + Ml^2$$

$$= Mk^2 + Ml^2 \qquad (2)$$

where k is the **radius of gyration** of the pendulum about the axis through C.G. Using Equation (2) in Equation (1), we get $T = 2\pi\sqrt{\frac{Mk^2+Ml^2}{Mgl}}$

$$T = 2\pi\sqrt{\frac{k^2+l^2}{gl}} = 2\pi\sqrt{\frac{k^2/l+l}{g}} = 2\pi\sqrt{\frac{L}{g}} \qquad (3)$$

where L is the length of the equivalent simple pendulum, given by

$$L = \left(k^2/l + l\right) \qquad (4)$$

Therefore, from (1) and (4), $g = 4\pi^2 \frac{L}{T^2}$ (5)

Equation (4) is a quadratic equation for l, which must have two roots l1 and l2 (say) and follows, $l_1 + l_2 = L$ and $l_1 l_2 = k^2$ (6)

for any particular value of ***l(l₁)***, there is a second point on the same side of C.G. and at a distance ***l*(k²/*l₁*)** from it, about which the pendulum will have the same time period. And the graph will look like:

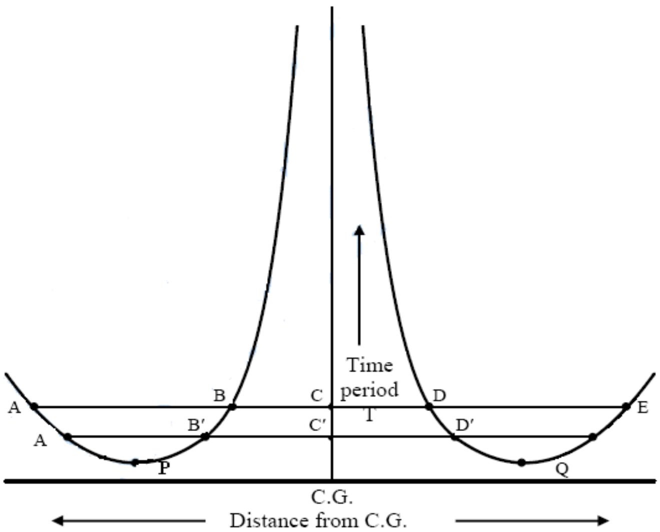


Figure 1: Expected variation of time period with distance of the point of suspension from C.G.

Ferguson's method for determination of g

Using Equations (4) and (5) we get

$$l^2 = \frac{g}{4\pi^2} lT^2 - k^2$$

A graph between l^2 and lT^2 should therefore be a straight line with slope, $\frac{g}{4\pi^2}$ as shown in (Figure2).

The intercept on the *y*-axis is –> k^2.

Acceleration due to gravity, $g = 4\pi^2 \times slope$

Radius of gyration, $k = \sqrt{(intercept)}$

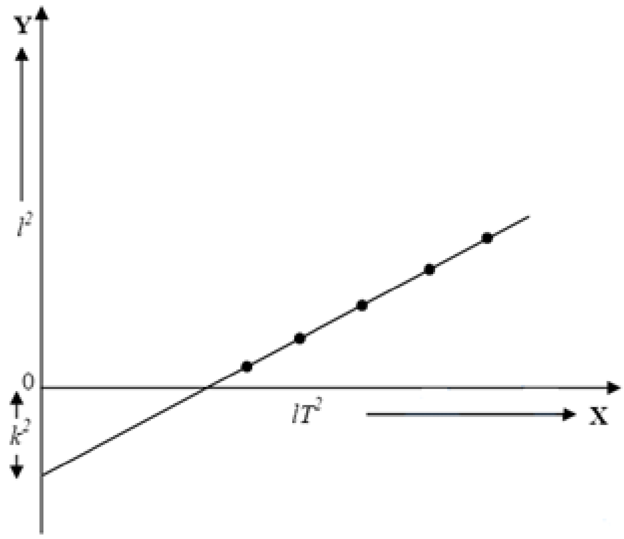


Figure2: Expected form of the graph between l^2 and lT^2.

PROCEDURE:

1. Balance the bar on a sharp wedge and mark the position of its C.G.
2. Fix the knife edges in the outermost holes at either end of the bar pendulum. The knife edges should be horizontal and lie symmetrically with respect to centre of gravity of the bar.
3. Check with spirit level that the glass plates fixed on the suspension wall bracket are horizontal. The support should be rigid.
4. Suspend the pendulum vertically by resting the knife edge at end A of the bar on the glass plate.
5. Displace the bar slightly to one side of the equilibrium position and let it oscillate with the amplitude not exceeding 5 degrees. Make sure that there is no air current in the vicinity of the pendulum.
6. Use the stop watch to measure the time for 20 oscillations. The time should be measured after the pendulum has had a few oscillations and the oscillations have become regular.
7. Measure the distance *l* from C.G. to the knife edge.

8. Record the results in Table 1. Repeat the measurement of the time for 20 oscillations and take the mean.
9. Suspend the pendulum on the knife edge of side B and repeat the measurements in steps 5-8 above.
10. Fix the knife edges successively in various holes on each side of C.G. and in each case, measure the time for 30 oscillations and the distance of the knife edges from C.G.

OBSERVATIONS:

TABLE 1: MEASUREMENT OF *T* AND *l*

Least count of stop-watch = ……sec.

S.No.	Side A up					Side B up				
	Time for 20 Oscillations (t)		t (mean)	T = t /20 (sec)	*l* (cm)	Time for 20 Oscillations (t)		t (mean)	T = t /20 (sec)	*l* (cm)
	1	2				1	2			
1										
2										
3										
4										
5										
6										
7										
8										
9										

Calculations

Plot a graph showing how the time period *T* depends on the distance from the center of suspension to C.G. (*l*). **Figure.1** shows the expected variation of time period with distance of the point of suspension from C.G.

Acceleration due to gravity (g)

Draw horizontal lines on the graph corresponding to a period, T_1 as shown in (Figure 1). For the line ABCDE

Radius of gyration (*k*) and g calculation:

Let $l_1 = 1/2\,(AC + CE) = 1/2\,AE$,

and $l_2 = 1/2\,(BC + CD) = 1/2\,BD$. (7)

And from (6), $L = 1/2\,(AE + BD)$

Hence, using this T1 and L in the formula for *g* (5) we get,

g = …………cm/sec^2.

The radius of gyration (6) can be evaluated using using the expression

$$k = \sqrt{l_1 l_2} = \text{.......... cm.}$$

Repeat it for another line A'B'C'D'E' (say for period T_2) and calculate the mean values for g and k.

If M is the mass of the bar pendulum, the moment of inertia of the bar pendulum is obtained using the equation

$$I = Mk^2$$

For **Ferguson's method, fill up** the following table to evaluate l^2 and lT^2 corresponding to all the measurements recorded in Table 1.

TABLE 2: CALCULATED VALUES OF (l^2) AND (lT^2):

S.No.	Side A up		Side B up		Mean values	
	l^2 (cm^2)	lT^2 (cm sec^2)	l^2 (cm^2)	lT^2 (cm sec^2)	l^2 (cm^2)	lT^2 (cm sec^2)
1						
2						
3						
4						
5						
6						
7						
8						
9						

Plot a graph of l^2 against lT^2 (as shown in Figure.2) and determine the values of the slope and the intercept on the l^2 axis.

Interference Obtained from Graph:

Slope of the graph = ……………… cm/sec^2.
Intercept = ……………. cm^2.
Acceleration due to gravity $g = 4\pi^2$ x slope = ………….. cm/sec^2.
Radius of gyration, $k = \sqrt{(\text{intercept})}$ ……. cm^2.

EX.NO. 3: YOUNG'S MODULUS OF WOOD USING A STRAIN GAUGE

AIM:

To determine the Young's modulus of a half meter wooden scale using a Strain Gauge.

APPARATUS REQUIRED:

A half meter scale with two identical strain gauges attached to one end of the scale, one strain gauge at the top and the other at the bottom; other end of the scale is attached to the table with a clamp; a circuit board with appropriate terminals to constitute a Wheatstone bridge network.

STRAIN GAUGE:

Young's modulus (Y) of the bar (scale) is defined by the ratio of stress (F/A) and tensile strain$(\Delta L/L)$,

$$\frac{F/A}{\Delta L/L} = Y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

where, F is the force applied (Newton), A is the cross-sectional area (m^2), ΔL is the change in length (m), L is the original change in length (m).

A strain gauge is a transducer whose electrical resistance varies in proportional to the amount of strain in the device. The most widely used gauge is metallic strain gauge which consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Fig.1).The cross-sectional area of the grid is minimized to reduce the effect of shear strain and Poisson strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistances.

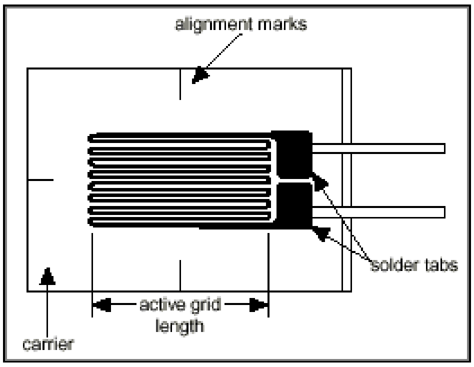


Figure.1

A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor (λ). Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain).

$$\frac{\Delta R/R}{\Delta L/L} = \lambda \ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots..(2)$$

The gauge factor (λ) for metallic strain gauge is typically around 2.

WHEATSTONE BRIDGE:

Measuring the strain with a strain gauge requires accurate measurement of very small change in resistance and such small changes in ***R*** can be measured with a Wheatstone bridge. A general Wheatstone bridge consists of four resistive arms with an excitation voltage, V_{EX}, that is applied across the bridge (Figure.2)

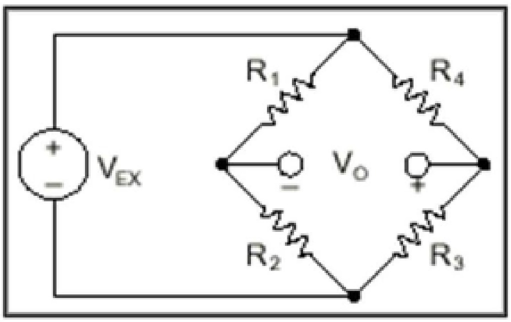


Figure 2. Wheatstone Bridge

The output voltage of the bridge, V_O, will be equal to:

$$V_O = \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2}\right].V_{EX} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

From this equation it is apparent that when $R_1/R_2=R_3/R_4$, the output voltage V_O will be zero. Under this condition, the bridge is said to be balanced. Any change in resistance in any arm of the bridge will result in a non-zero output voltage. Therefore, if we replace R_4 in Figure 2 with an active strain gauge, any change in the strain gauge resistance will unbalance the bridge and produce a nonzero output voltage. If the nominal resistance of the strain gauge is designed as R_G, then the strain induced change in resistance ΔR, can be expressed as

$$\Delta R = R_G.\lambda.strain\ldots\ldots\ldots\ldots\ldots.(4)$$

Assuming that $R_1=R_2$ and $R_3=R_G$, the bridge equation above can be rewritten to express V_O/V_{EX} as a function of strain.

Ideally, we would like the resistance of the strain gauge to change only in response to applied strain. However, strain gauge material, as well as the specimen material on which the gauge is mounted, will also respond to changes in temperature. Strain gauge manufacturers attempt to minimize sensitivity to temperature by processing the gauge material to compensate for the thermal expansion of the specimen material for which the gauge is intended. While compensated gauges reduce the thermal sensitivity, they do not totally remove it. By using two strain gauges in the bridge, the effect of temperature can be further minimized. For example, in a strain gauge configuration where one gauge is active ***(R_G+ΔR),*** and a second gauge is placed transverse to the applied strain. Therefore, the strain has little effect on the second gauge, called the dummy gauge. However any changes in temperature will affect both gauges in the same way. Because the temperature changes are identical in the two gauges, the ratio of their resistance does not change, the voltage V_0 does not change, and the effects of the temperature change are minimized.

The sensitivity of the bridge to strain can be doubled by making both gauges active in a half bridge configuration. Figure.3 illustrates a bending beam application with one bridge mounted in tension***(R_G+ΔR)*** and the other mounted in compression **(R_G-ΔR).**This half bridge configuration, whose circuit diagram is also illustrated in Figure.3 yields an output voltage that is linear and approximately doubles the output of the quarter bridge.

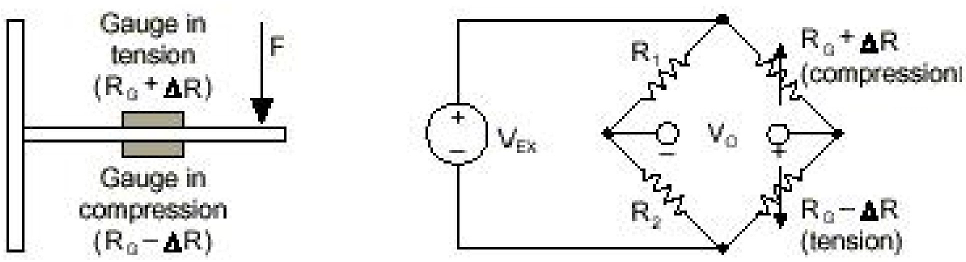


Figure.3

And in this experiment, we aim to determine the Young's modulus of a half meter wooden bar by loading it with a mass of **"*m*"** gram. For a beam of rectangular cross section with breadth b and thickness ***d,*** the moment of inertia ***I***, is

$$I = b\,d^3/12 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots.(5)$$

The moment of force/restoring couple is **Y.I/ r_c** where r_c is the radius of curvature of the bending beam. The Young's modulus is calculated by assuming that at equilibrium, the bending moment is equal to the restoring moment.

PROCEDURE:

1. Clamp the beam to the table in such a way that the strain gauges are close to the clamped end. Load and unload the free end of the beam a number of times.
2. Make the connections as given in the circuit diagram (Figure.4)

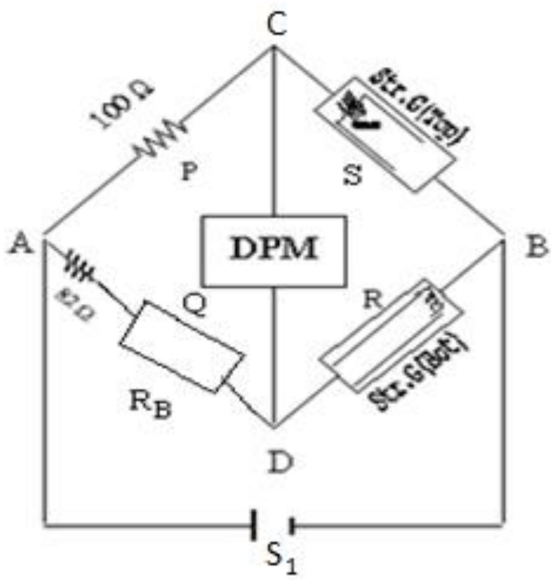
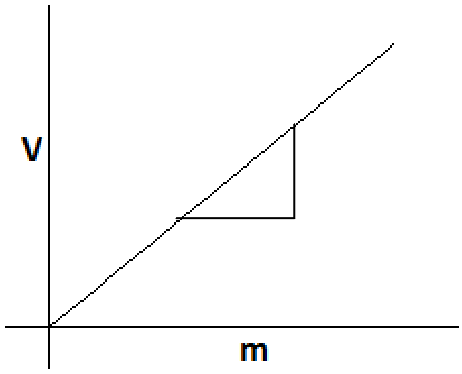


Figure.4

P=100Ω resistor, S_1 =10 mA current source, DPM= a voltmeter with digital panel. R=S= strain gauge resistance~120Ω with a gauge factor λ=2.2, Q=82Ω (plus the resistance of the rheostats) all in series.

3. Switch ON the constant current source (S_1) and DPM.
4. Balance the bridge using the rheostats. At this stage the DPM will read or very nearly zero. Note that, this is done at no load (only with the dead load).
5. Load the beam with a hanger of mass ***'m'*** gm suspending it as close to the free end of the scale as possible. Note the DPM reading. (Note that as you are about to take a reading the last digit will be changing about the actual steady value. Take at least 10 readings continuously and take the average these ten).
6. Increase the load in steps of ***m*** **(50) gm**, up to **5*m*** gm and take the readings each time.
7. Unload the beam <u>from **5*m*** down to zero in steps of ***m*** gm at a time</u> and note the DPM reading each time.
8. To check reproducibility, repeat all the above process taking readings while loading and unloading in steps of ***m*** gm.
9. Draw a graph between ***m*** along X axis and unbalanced voltage ***V*** along Y axis. Determine the slope of the graph **(*dV/dm*)**



10. Note the distance between the center of the strain gauges and the point of application of the load **(*L*).**
11. Measure the breadth of the beam using slide calipers **(*b*).**
12. Measure the thickness of the beam using a screw gauge **(*d*)**.
13. Young's modulus of the material of the beam, which is nothing but stress to strain ratio, is given by the following expression (Working formula).

$$Y = \frac{6gL\lambda RI}{bd^2[1 + (R/P)]\frac{dV}{dm}} \dots\dots\dots\dots\dots\dots\dots\dots. (5)$$

where

- g is the acceleration due to gravity,
- **λ** is the gauge factor (for metal strain gauge λ =2.2).
- I is the output current from the source S_1.
- R is the resistance of strain gauge.
- $\frac{dV}{dm}$ is slope of the ***m*** Vs ***V*** curve

TABULATION:

Load (gram) → / ↓ DPM reading (mV)	0m	1m	2m	3m	4m
1) Loading V_1					
2) Unloading V_2					
3) Mean of V_1+V_2					

RESULT:

Thus, the Young's modulus of the given wooden scale is, Y =-----------------N/m^2.

EX.NO.4: DETERMINATION OF COEFFICIENT OF STATIC FRICTION

OBJECTIVE: To measure the static coefficient of friction for several combinations of material surfaces.

APPARATUS REQUIRED: Inclined plane, Metal block, pull-push meter, set of weights and materials with different surfaces.

FORMULA: Coefficient of static friction, $\mu_S = \frac{f_S}{N}$

Angle of static friction, $\varphi s = \tan^{-1}(\mu_S)$

where,

f_S – Maximum static friction force (N)

N – Normal force applied (N)

THEORY:

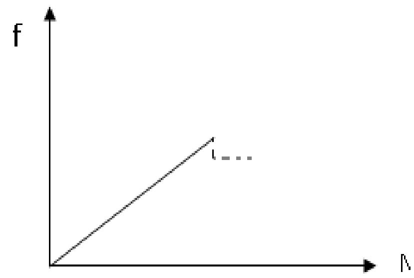


Figure 1a

The coefficient of static friction (μ_S) can be measured experimentally for an object placed on a flat surface and pulled by a known force. The friction force depends on the coefficient of static friction and the Normal force (N) on the object from the surface. When the object just begins to slide, the friction force will attain its maximum value as shown in Figure 1a.

The forces acting on a body kept on an inclined plane are shown in Figure 1. W is the weight of the body (W = mg), N is the normal force from the plane and f is the frictional force. Generally this situation is analyzed by resolving the forces into components parallel and perpendicular to the plane, as shown in Figure 1.

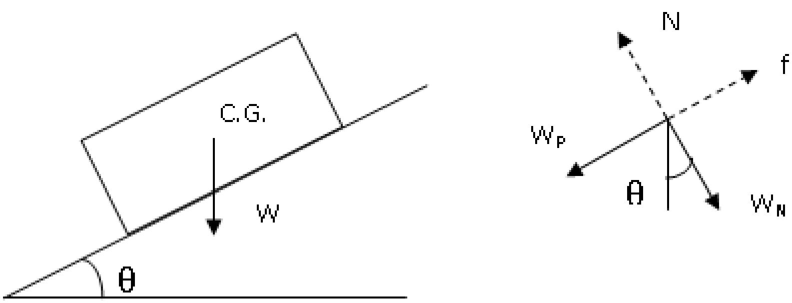


Figure 1.

The weight W is resolved into two components acting along the plane W_P and normal to plane W_N which are balanced by frictional force f and the normal force N, respectively while the body is stationary. When motion is impending, the friction force f attains its maximum value f_S. $f_S = W_P = W \sin\theta_S$

The angle at which the motion is impending is called the 'Angle of repose'.

$$\mu_S = \frac{f_S}{N} = \frac{W\sin\theta_S}{W\cos\theta_S} \quad \Rightarrow \quad \theta s = \tan^{-1}(\mu_S),$$

Angle of repose is equal to the angle of static friction.

Procedure

1. **Place the metal block on the rubber sheet given.**
2. **Place some weight at the centre of the metal block and pull it horizontally using the pull-push meter.**
3. **Note the reading shown on the pull-push meter as motion is impending.**
4. **Keep the metal block on an inclined wooden plane, whose initial inclination does not exceed 10°, with the rubber sheet between metal block and wooden plane.**
5. **Slowly increase the angle of wooden plane.**
6. **Note the inclination at which motion of metal block is impending, i.e. the angle of repose for the given condition.**
7. **Increase the load on metal block and repeat procedure from step 1.**
8. **Above experiment can be repeated for different material surfaces.**

TABLE 1: TO FIND THE COEFFIENT OF STATIC FRICTION (μ_S) ON HORIZONTAL PLANE

Trial No.	Surface Type	Total Weight of metal block, W = N	Max. friction force, i.e. Pull-Push meter reading, f_S	Co-efficient of static friction, $\mu_S = f_S / N$	Angle of static friction, $\phi_s = \tan^{-1}(\mu_S)$
1	---------				
2					
3					

**** Repeat this for other given surfaces also**

TABLE 2: TO FIND THE COEFFIENT OF STATIC FRICTION (μ_S) ON INCLINED PLANE

Trial No.	Surface Type	Length *(l)*	Height *(h)*	Angle of repose, (θ_S)	μ_S=tan(θ_S)
1					
2	--------				
3					

**** Repeat this for other given surfaces**

Graph

Plot a graph between the normal force (N) and the frictional force (f_S) obtained while the metal block was kept on the horizontal plane.

TABLE 3: Comparison of (i) values of μ_S, and (ii) the values of θ_S and ϕ_S.

Trail No.	Surface Type	Angle of Static Friction (φ_s)	Angle of repose, (θ_S)	μ_S (From Horizontal Plane)	μ_S , (From Inclined Plane)

EX NO. 5 : TENSILE TEST

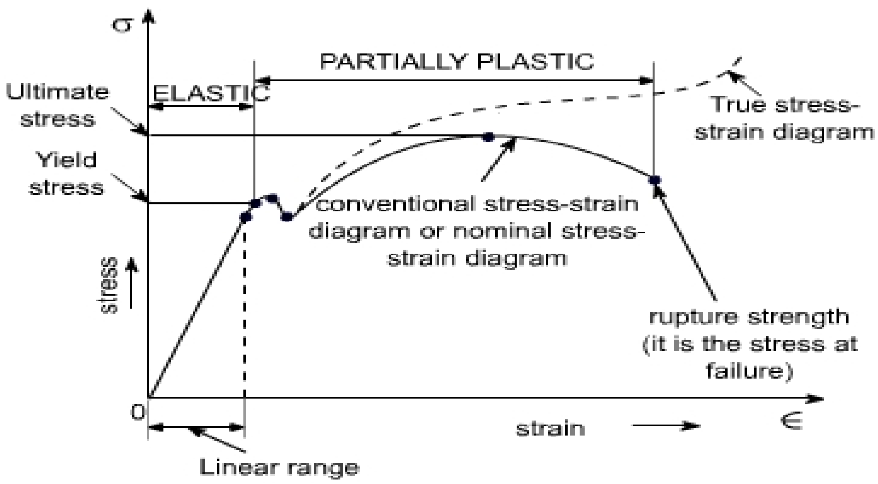
AIM: To study the response of the given specimens subjected to tensile load.

DESCRIPTION:

The engineering tension test is widely used to provide basic design information on the strength of the materials and as an accepted test for the specification of the materials. In the tension test a specimen is subjected to a continually increasing uniaxial tensile force while simultaneous observations are made of the elongation of the specimen.

APPARATUS/ INSTRUMENT REQUIRED:

1. **INSTRON tensile testing machine, Capacity-2 kN, Vernier caliper and scale, Test specimens- as per ASTM standards**



PROCEDURE:

1. **Measure and record the initial dimension of the specimen (gauge length-L_0, width w_0, thickness t_0, cross section area $A_o = w_0 \times t_0$).**
2. **Fix the test specimen between fixed and movable jaws of machine.**
3. **Reset the load to zero.**
4. **Operate the machine till the specimen fractures.**
5. **Measure and record the final configuration of the specimen (gauge length L_f, width w_f, thickness t_f, cross section area $A_f = w_f \times t_f$).**
6. **Repeat the experiment for different strain rate (rate of loading).**

7. **Using the data acquired by the system, construct the stress-strain curves and find the various parameters as listed in the calculation.**

OBSERVATION:

Sl. No	Material, Strain rate & Load	Dimensions (mm)	Fracture dimension (mm)
1	**Aluminium** **Strain rate:** **Load:**	L_o= w_o= t_o= A_o =	L_f= w_f= t_f= A_f =
2	**Nylon** **Strain rate:** **Load:**	L_o= w_o= t_o= A_o =	L_f= w_f= t_f= A_f =

CALCULATIONS:

1. $A_0 = \quad mm^2$
2. $A_f = \quad mm^2$
3. **Ultimate tensile strength,** $S_U = \frac{P_{Max}}{A_0}(N/mm^2)$ **(Neck formation starts)**

Where, P_{max} is the at the maximum of the curve

Yield strength, $S_0 \Rightarrow$ **load at which sample starts getting Plastic deformation (ie the curve starts deviation from linear nature)**

Note: Yield strength is the stress required to produce a small specified amount of plastic deformation. The usual definition of this property is the offset yield strength determined by the stress corresponding to the intersection of the stress-strain curve and a line parallel to the elastic part of the curve offset by a strain of 0.2%.

4. **Breaking stress,** $S_f = \frac{P_f}{A_0}(N/mm^2)$

where, P_f is the breaking/fracture load (load at occurrence of facture) .

5. **Strain,** $e_f = \frac{L_f - L_0}{L_0}$

6. **Reduction in area at fracture,** $q = \frac{A_f - A_0}{A_0}$

7. **Modulus of elasticity,** ***E = Slope of initial linear portion of the curve*,**

8. **Resilience,** $U_R = \frac{S_0^2}{2E}$ **N/mm^2.**

9. **Toughness,** $U_R = \frac{S_0 + S_U}{2} e_f$ **N/mm^2.**

INFERENCE:

1. **Compare the results and state which material has high strength, toughness, ductility and stiffness.**

2. **State the effect of strain rate in material response.**