

**calculation of intraocular lens
power using the texas instruments ti
programmable 59 calculator**

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Programs have been published for the Texas Instruments SR52 programmable calculator to calculate intraocular lens (IOL) implant power.¹ The SR52 calculator is no longer available and has been superseded by the Texas Instruments TI Programmable 59 (TI59) calculator. The TI59 has more computing power and a more flexible output format. The TI59 with the PC-100A printer attachment can provide printed output in tape form with a heading containing up to twenty characters and a printed label identifying each piece of input data and each calculated result. The heading and labels reduce confusion in interpreting the tape output and aid in the detection of errors in inputting the data. The tape provides a permanent record of the calculation performed and input data used.

The formula used for the calculation of lens implant power for emmetropia is Colenbrander's equation as modified by Drews²:

$$D_e = \frac{1336}{a - (d + 0.05)} - \frac{1336}{(1336/K) - (d + 0.05)}$$

where D_e = the dioptric power in aqueous of the IOL,

a = the axial length of the eye in millimeters,

d = the distance between the anterior vertex of the cornea and the IOL in millimeters,

and K = average corneal power in diopters.

Binkhorst's formula¹ is used for the calculation of refractive error expected with a given IOL power:

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$$R_s = \frac{1336(4r - a)}{1336[V(4r - a) + 0.0032r] - \frac{D(a-d)(4r - d)}{D(a-d)[V(4r - d) + 0.003dr]}$$

where R_s = the spectacle refraction in diopters,

r = the radius of curvature of the anterior surface of the cornea in millimeters,

a = the axial length of the eye in millimeters,

D = the known dioptric power in aqueous of an IOL,

and V = the vertex distance of the patient's spectacles in meters (program entry is in millimeters).

Like Drews², we set $4r$ in Binkhorst's equation equal to $1336/K$. This is equivalent to assuming the index of refraction of the cornea to be different than the value of $4/3$ assumed by Binkhorst. The assumed value of the corneal index will now depend on the keratometer used to measure the cornea. The most commonly assumed instrument value for the corneal index of refraction is 1.3375.

The program calculates the IOL power for emmetropia, the expected refractive error for aphakia, the IOL power for ametropia (-1.50 D spectacle), and for a series of steps of IOL powers starting at some D (minimum) and increasing by 1.0 D for each successive step. The program will accept up to three keratometer readings on each axis and uses the averaged value of these in the IOL calculation. Unless specified by the user, the program assumes the following values for the parameters d , V , D (minimum), and the index of refraction (N):

$d = 3.5$ mm, (LBL A')

$V = 12.0$ mm, (LBL C')

D (minimum) = $16D$, (LBL C)

R_s (for ametropia) = $-1.5D$ (ST022)

$N = 1336$, (ST029)

These values may be changed at the time of program execution by entering the desired values in the proper register. To do a calculation of IOL power, the calculator is cleared and the program steps entered into memory by insertion of a prerecorded magnetic card. The equation constants are loaded by pressing the keys RST and R/S to initialize the program. Unless the constants are changed, this need be performed only once after entering the program tape. Next the axial length is entered into A and the values of corneal power into B (or corneal radius into

D'). At this point one may elect to change the preprogrammed values of the parameters d, V, and D (minimum) by entering the desired value in the proper register. To program a heading for the tape (optional), the reader is referred to Table 1 and the TI59 manual for detailed instructions. The heading is printed by pressing E. To run the programs, D is pressed. This will result in the calculating and printing in order of the following: 1) axial length (A.L.), 2) first axis K reading (K-1), 3) second axis K reading (K-2), 4) average K reading (K-AV), 5) equivalent radius of cornea (K-mm), 6) anterior chamber depth (A.C.), 7) spectacle vertex distance (V-s), and 8) IOL power for emmetropia (D-EM). Next, pressing the R/S key will result in the calculation of R_s for aphakia and the printing of the IOL power for aphakia (which, of course, is zero) and the value of the expected aphakic refraction, in that order. The program will continue with the calculation of the IOL power required to make the eye 1.5 D myopic and the printing of the IOL power and R_s . Pressing R/S

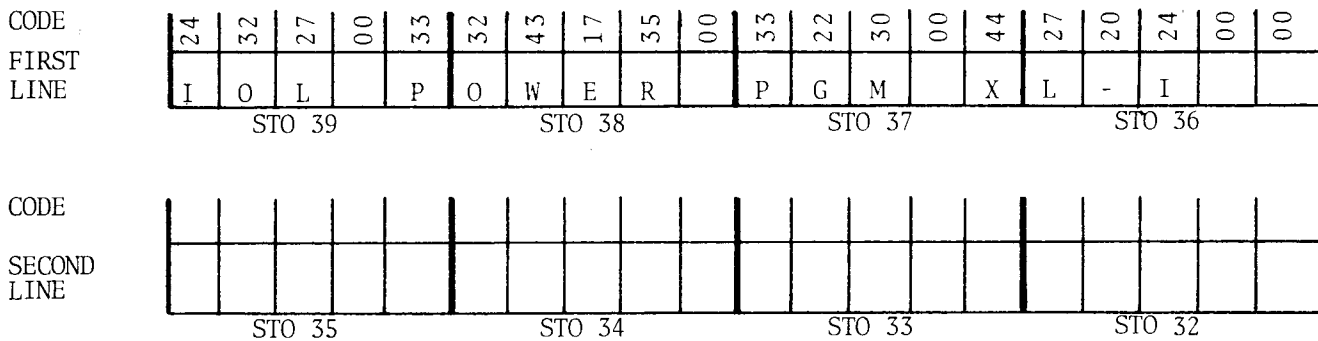
again results in the calculation of R_s for D (minimum) and in the printing of the IOL power and R_s . Now, each successive operation of the R/S key will cause D to be incremented by 1.0 diopter and a new value of R_s to be calculated and printed.

The printout for a sample calculation is shown along with constants and notes on preparation and data entry (Table 2). The detailed program instructions and program steps are included on the Texas Instruments programming forms (Figure 2).

When a printed heading is desired, sides 1 and 2 of the TI59 program are read as normal without changing the initial program partition of 479.59 (Figure 1). The calculation is then repartitioned for

1 ←		→ 2		
I.O.L. Program XL-I				479.59
A.C.*	Ave K Pgm*	V-S*	K-1 & 2 (mm).	Restart
A.L.	K-1 & 2 (D)	D-Min*	RUN	Prt Hdg*

Figure 1. (Kollarits, CR) Marking for Sides 1 and 2 of TI-59 Program Tape



		UNITS DIGIT									
		0	1	2	3	4	5	6	7		
TENS DIGIT	0	0	1	2	3	4	5	6	7		
	1	7	8	9	A	B	C	D	E		
	2	-	F	G	H	I	J	K	L		
	3	M	N	O	P	Q	R	S	T		
	4	.	U	V	W	X	Y	Z	+		
	5	×	÷	√	∞	e	()	±		
	6	↑	↓	∫	/	=	*	×	∑		
	7	∑	?	÷	∞	∏	∆	∏	∑		

To Use:

1. Write name in space "Second Line".
2. Convert to appropriate code.
3. Read "Heading" tape sides 3 & 4 as described in Page 1 of 2.
4. Enter groups of 10 code numbers and store in appropriate register (STO).
5. When all registers are filled (use zeros where no character is desired), test by pressing E.
6. If printout is correct, re-record tape by pressing 3/2nd/write, then enter tape side 3. Repeat pressing 4/2nd/write and side 4.

Table 1. Printed Heading Coding Chart

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS					
000	01	1		055	61	GTO		110	43	RCL						
001	03	3		056	00	00		111	27	27						
002	03	3		057	51	51		112	95	=						
003	06	6		058	76	LBL		113	12	B						
004	42	STD		059	12	B		114	76	LBL						
005	29	29		060	87	IFF		115	14	D						
006	93	.		061	00	00		116	58	FIX						
007	00	0		062	35	1/X		117	02	02						
008	01	1		063	86	STF		118	87	IFF						
009	02	2		064	00	00		119	01	01						
010	42	STD		065	42	STD		120	48	EXC						
011	28	28		066	20	20		121	01	1						
012	03	3		067	91	R/S		122	06	6						
013	03	3		068	76	LBL		123	42	STD						
014	07	7		069	35	1/X		124	09	09						
015	93	.		070	22	INV		125	76	LBL						
016	05	5		071	86	STF		126	48	EXC						
017	42	STD		072	00	00		127	01	1						
018	27	27		073	42	STD		128	03	3						
019	03	3		074	19	19		129	02	2						
020	93	.		075	91	R/S		130	00	0						
021	05	5		076	76	LBL		131	02	2						
022	42	STD		077	13	C		132	07	7						
023	24	24		078	86	STF		133	69	DP						
024	03	3		079	01	01		134	04	04						
025	93	.		080	42	STD		135	43	RCL						
026	05	5		081	09	09		136	21	21						
027	05	5		082	91	R/S		137	69	DP						
028	42	STD		083	76	LBL		138	06	06						
029	23	23		084	16	A'		139	02	2						
030	01	1		085	42	STD		140	06	6						
031	93	.		086	24	24		141	02	2						
032	05	5		087	85	+		142	00	0						
033	94	+/-		088	93	.		143	00	0						
034	42	STD		089	00	0		144	02	2						
035	22	22		090	05	5		145	69	DP						
036	91	R/S		091	95	=		146	04	04						
037	76	LBL		092	42	STD		147	43	RCL						
038	11	A		093	23	23		148	20	20						
039	42	STD		094	91	R/S		149	69	DP						
040	21	21		095	76	LBL		150	06	06						
041	91	R/S		096	18	C'		151	02	2						
042	76	LBL		097	55	+		152	06	6						
043	17	B'		098	01	1		153	02	2						
044	36	PGM		099	00	0		154	00	0						
045	17	17		100	00	0		155	00	0						
046	10	E'		101	00	0		156	03	3						
047	03	3		102	95	=		157	69	DP						
048	36	PGM		103	42	STD		158	04	04						
049	17	17		104	28	28		159	43	RCL						
050	11	A		105	91	R/S		MERGED CODES								
051	91	R/S		106	76	LBL		62	PGM	IND	72	STD	IND	83	GTO	IND
052	36	PGM		107	19	D'		63	EXC	IND	73	RCL	IND	84	OP	IND
053	17	17		108	35	1/X		64	PRG	IND	74	SUM	IND	92	INV	SBR
054	12	B		109	65	X		TEXAS INSTRUMENTS INCORPORATED								

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
160	19	19		215	06	06		270	85	+	
161	69	DP		216	01	1		271	43	RCL	
162	06	06		217	03	3		272	29	29	
163	85	+		218	02	2		273	55	÷	
164	43	RCL		219	00	0		274	53	(
165	20	20		220	01	1		275	43	RCL	
166	95	=		221	05	5		276	23	23	
167	55	÷		222	69	DP		277	75	-	
168	02	2		223	04	04		278	43	RCL	
169	95	=		224	43	RCL		279	16	16	
170	42	STD		225	24	24		280	95	=	
171	18	18		226	69	DP		281	69	DP	
172	35	1/X		227	06	06		282	06	06	
173	65	×		228	04	4		283	98	ADV	
174	43	RCL		229	02	2		284	91	R/S	
175	29	29		230	02	2		285	71	SBR	
176	95	=		231	00	0		286	45	YX	
177	42	STD		232	03	3		287	25	CLR	
178	16	16		233	06	6		288	69	DP	
179	02	2		234	69	DP		289	06	06	
180	06	6		235	04	04		290	71	SBR	
181	02	2		236	43	RCL		291	33	X ²	
182	00	0		237	28	28		292	93	.	
183	01	1		238	65	×		293	00	0	
184	03	3		239	01	1		294	00	0	
185	69	DP		240	00	0		295	00	0	
186	04	04		241	00	0		296	07	7	
187	43	RCL		242	00	0		297	05	5	
188	18	18		243	95	=		298	65	×	
189	69	DP		244	69	DP		299	43	RCL	
190	06	06		245	06	06		300	16	16	
191	22	INV		246	22	INV		301	65	×	
192	58	FIX		247	58	FIX		302	42	STD	
193	02	2		248	01	1		303	15	15	
194	06	6		249	06	6		304	43	RCL	
195	02	2		250	02	2		305	21	21	
196	00	0		251	00	0		306	85	+	
197	03	3		252	01	1		307	53	(
198	00	0		253	07	7		308	43	RCL	
199	03	3		254	03	3		309	16	16	
200	00	0		255	00	0		310	75	-	
201	69	DP		256	69	DP		311	43	RCL	
202	04	04		257	04	04		312	21	21	
203	58	FIX		258	58	FIX		313	54)	
204	02	02		259	02	02		314	42	STD	
205	43	RCL		260	43	RCL		315	14	14	
206	18	18		261	29	29		316	65	×	
207	35	1/X		262	55	÷		317	43	RCL	
208	65	×		263	53	(		318	28	28	
209	43	RCL		264	43	RCL		319	95	=	
210	27	27		265	21	21		MERGED CODES			
211	95	=		266	75	-		62	Pgm	Ind	
212	42	STD		267	43	RCL		72	STO	Ind	
213	17	17		268	23	23		83	GTO	Ind	
214	69	DP		269	54)		63	Exc	Ind	
								73	RCL	Ind	
								84	DP	Ind	
								64	Pic	Ind	
								74	SUM	Ind	
								92	INV	SBR	

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LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
320	65	*		375	43	RCL		430	09	09	
321	43	RCL		376	13	13		431	85	+	
322	29	29		377	95	=		432	43	RCL	
323	95	=		378	69	DP		433	26	26	
324	42	STD		379	06	06		434	95	=	
325	13	13		380	98	ADV		435	55	÷	
326	43	RCL		381	71	SBR		436	53	(
327	15	15		382	33	X²		437	43	RCL	
328	65	*		383	43	RCL		438	13	13	
329	43	RCL		384	22	22		439	85	+	
330	24	24		385	69	DP		440	43	RCL	
331	85	+		386	06	06		441	11	11	
332	53	(		387	71	SBR		442	65	*	
333	43	RCL		388	45	YX		443	43	RCL	
334	16	16		389	43	RCL		444	09	09	
335	75	-		390	26	26		445	95	=	
336	43	RCL		391	75	-		446	69	DP	
337	24	24		392	43	RCL		447	06	06	
338	54	)		393	13	13		448	91	R/S	
339	42	STD		394	65	*		449	69	DP	
340	12	12		395	43	RCL		450	29	29	
341	65	*		396	22	22		451	10	E'	
342	43	RCL		397	95	=		452	76	LBL	
343	28	28		398	55	÷		453	45	YX	
344	95	=		399	53	(		454	02	2	
345	65	*		400	43	RCL		455	04	4	
346	53	(		401	11	11		456	03	3	
347	43	RCL		402	65	*		457	02	2	
348	24	24		403	43	RCL		458	02	2	
349	75	-		404	22	22		459	07	7	
350	43	RCL		405	75	-		460	69	DP	
351	21	21		406	43	RCL		461	04	04	
352	95	=		407	25	25		462	92	RTN	
353	42	STD		408	95	=		463	76	LBL	
354	11	11		409	69	DP		464	33	X²	
355	43	RCL		410	06	06		465	03	3	
356	24	24		411	98	ADV		466	05	5	
357	75	-		412	91	R/S		467	02	2	
358	43	RCL		413	76	LBL		468	00	0	
359	21	21		414	10	E'		469	03	3	
360	95	=		415	22	INV		470	06	6	
361	65	*		416	86	STF		471	69	DP	
362	43	RCL		417	01	01		472	04	04	
363	12	12		418	71	SBR		473	92	RTN	
364	95	=		419	45	YX		474	00	0	
365	42	STD		420	43	RCL		475	00	0	
366	25	25		421	09	09		476	00	0	
367	43	RCL		422	69	DP		477	00	0	
368	14	14		423	06	06		478	00	0	
369	65	*		424	71	SBR		479	00	0	
370	43	RCL		425	33	X²					
371	29	29		426	43	RCL					
372	55	÷		427	25	25					
373	42	STD		428	65	*					
374	26	26		429	43	RCL					

MERGED CODES

62	Pgm	Ind	72	STD	Ind	83	GTO	Ind
63	Inv	Ind	73	RCL	Ind	84	Op	Ind
64	Prd	Ind	74	SUM	Ind	92	INV	SBR

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Figure 3. (Kollarits, CR) Optional Heading Program

TITLE I.O.L. XL-1 Heading PAGE 1 OF 2

PROGRAMMER W. A. Lindgren DATE 12-08-77

Partitioning (Op 17) 15, 5, 9, 4, 9 Library Module Master Printer PC-100A Cards 1

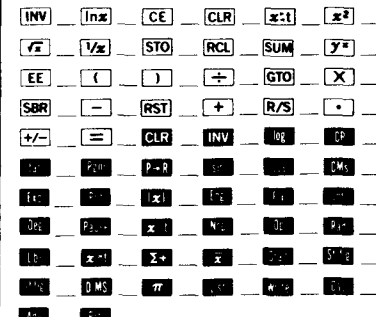
PROGRAM DESCRIPTION

After entering main program card, the partitioning is reallocated and the Heading program card is entered. The heading should be printed before each calculation to identify tape.

Sample below prints John Smith, M.D. Use Table 1 for recoding physician's name in storage registers 32, 33, 34 & 35. This is then used to rerecord Sides 3 and 4.

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Clear for tape reading	-	INV FIX'	0.
2	Repartition	5	OP' 17	559.49
3	Read Side 3 of I.O.L. XL-I	-	CLR INV WRT'	3
4	Read Side 4 of I.O.L. XL-I	-	CLR INV WRT'	4
5	Print Heading	-	E	
	Prints:			
	To Rerecord Tape Sides 3 and 4			
1	Clear for tape recording	-	INV FIX'	0.
2	Record Side 3	3	WRT'	3.
3	Insert Tape Side 3 into lower slot at right side of the left side.		TI-59 and remove from	
4	Record Side 4	4	WRT'	4
	Repeat Step 3 for Side 4			

USER DEFINED KEYS	DATA REGISTERS (INV LSR)		LABELS (Op 08)							
A	3 ⁰	4 ⁰ 3113301740								
B	3 ¹	4 ¹ 4040404040								
C	3 ²	4 ² 4040404040								
D	3 ³ 5730160000	4 ³ 4040404040								
E Print Heading	3 ⁴ 3630243723	4 ⁴ 1613371740								
A'	3 ⁵ 2532233100	4 ⁵ 4040404040								
B'	3 ⁶ 2720240000	4 ⁶ 4040321640								
C'	3 ⁷ 3322300044	4 ⁷ 4032364040								
D'	3 ⁸ 3243173500	8								
E'	3 ⁹ 2432270033	9								
FLAGS	0	1	2	3	4	5	6	7	8	9

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
480	76	LBL		535	69	OP					
481	15	E		536	04	04					
482	22	INV		537	69	OP					
483	58	FIX		538	05	05					
484	43	RCL		539	98	ADV					
485	39	39		540	43	RCL					
486	69	OP		541	44	44					
487	01	01		542	69	OP					
488	43	RCL		543	01	01					
489	38	38		544	43	RCL					
490	69	OP		545	45	45					
491	02	02		546	69	OP					
492	43	RCL		547	02	02					
493	37	37		548	43	RCL					
494	69	OP		549	46	46					
495	03	03		550	69	OP					
496	43	RCL		551	03	03					
497	36	36		552	43	RCL					
498	69	OP		553	47	47					
499	04	04		554	69	OP					
500	69	OP		555	04	04					
501	05	05		556	69	OP					
502	43	RCL		557	05	05					
503	35	35		558	98	ADV					
504	69	OP		559	91	R/S					
505	01	01									
506	43	RCL									
507	34	34									
508	69	OP									
509	02	02									
510	43	RCL									
511	33	33									
512	69	OP									
513	03	03									
514	43	RCL									
515	32	32									
516	69	OP									
517	04	04									
518	69	OP									
519	05	05									
520	98	ADV									
521	43	RCL									
522	40	40									
523	69	OP									
524	01	01									
525	43	RCL									
526	41	41									
527	69	OP									
528	02	02									
529	43	RCL									
530	42	42									
531	69	OP									
532	03	03									
533	43	RCL									
534	43	43									

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

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See Table 1
to Change
John Smith, M.D. †

IDL POWER PGM XL-I ← If used, Press E
JOHN SMITH, MD

NAME.....

DATE.....DD..DS..

24.32	A-L	← Input data into A,
42.25	K-1	B, etc., Press D
43.12	K-2	
42.69	K-A	
7.82	K-MM	
3.50	A-C	
12.00	V-S	
16.18	D-EM	
0.00	IDL	← Press R/S
10.66	R-S	
-1.50	R-S	
17.97	IDL	
16.00	IDL	← Press R/S
0.09	R-S	
17.00	IDL	← Press R/S
-0.71	R-S	
18.00	IDL	← Press R/S
-1.52	R-S	
19.00	IDL	← Press R/S
-2.36	R-S	
20.00	IDL	← Press R/S
-3.21	R-S	
21.00	IDL	← Press R/S
-4.09	R-S	

Table 2. Sample Calculation from the I.O.L. XL-I Program

559.49, and sides 3 and 4 of a second tape, containing the heading printout information, are then recorded. The format shown in Table 1 includes information on how to enter the second line of printing into the storage registers for recording onto the second tape.

The complete description, instructions and listing for the basic lens power calculation program are included on the four pages of TI Program Record forms, entitled I.O.L. XL-I (Figure 2). The optional heading program is included on the two pages of the form, entitled I.O.L. Ex-I Heading (Figure 3). Magnetic cards for this program are available from any of the authors at no charge.

All forms (Figures 2, 3) have been reproduced with the permission of Texas Instruments, Incorporated.

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