PHYSICS ENGINEERING ELECTRONICS

PROGRAM LIBRARY

sinclair

Enterprise Programmable

QUICK GUIDE TO USING THE LIBRARY

Always refer to the instruction book until you are familiar with the use of the calculator.

To enter a program:

> Enter goto/0/0/prog
> Then enter the keystrokes as given in the table on the right hand side of each program in the library.
> Then enter prog/goto/0/1

Always remember to press [▲] when the upper case of a key is required.

To use a program follow the pre-execution (if applicable) and execution sequence given with it. Remember to wait till the display lights up before entering a number in the middle of an execution sequence.

If you think you have made a mistake in program entry, check the program with some data for which you know the correct answer. If there is an error, either re-enter the program, or find the error using the check codes and correct it as detailed in the instruction book.

If you make a mistake in the execution sequence, it is generally necessary to enter C/goto/0/1 and to start the pre-execution and execution sequences again.

It is a good idea to press [C] to clear any previous results before starting an execution sequence or, indeed, any calculation.

A program can be halted in the middle of execution by entering /stop/ (i.e. pressing [▲] [+/–]).

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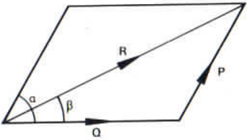
PARALLEL-OGRAM LAW OF VECTORS (FORCES, VELOCITIES ETC.)



$$R = \sqrt{(P^2 + Q^2 + 2PQ \cos \alpha)}$$

$$\beta = \text{arc sin}\left(\frac{Q}{R} \sin \alpha\right)$$

Execution:

P/run/Q/run/α/run/ R/run/ β

KEY	#	KEY	#
HALT	00	goto	40
sto	01	0	41
0	02	0	42
stop	03		43
sto	04		44
1	05		45
stop	06		46
sto	07		47
2	08		48
cos	09		49
×	10		50
rcl	11		51
0	12		52
×	13		53
rcl	14		54
1	15		55
×	16		56
2	17		57
+	18		58
rcl	19		59
0	20		60
x^2	21		61
+	22		62
rcl	23		63
1	24		64
x^2	25		65
=	26		66
$\sqrt{x}$	27		67
stop	28		68
1/x	29		69
×	30		70
rcl	31		71
0	32		72
×	33		73
rcl	34		74
2	35		75
sin	36		76
=	37		77
arc	38		78
sin	39		79

CONSTANT ACCELERATION MOTION

KEY	#	KEY	#
HALT	00	stop	40
sto	01	×	41
0	02	rcl	42
stop	03	1	43
sto	04	×	44
1	05	2	45
stop	06	+	46
sto	07	rcl	47
2	08	0	48
×	09	x^2	49
rcl	10	=	50
1	11	$\sqrt{x}$	51
+	12	goto	52
rcl	13	4	53
0	14	0	54
=	15	−	55
stop	16	stop	56
×	17	sto	57
rcl	18	0	58
2	19	÷	59
−	20	(	60
(	21	÷	61
rcl	22	2	62
1	23	+	63
×	24	rcl	64
rcl	25	0	65
2	26	=	66
x^2	27	sto	67
÷	28	0	68
2	29	stop	69
)	30	)	70
=	31	=	71
goto	32	stop	72
0	33	×	73
6	34	rcl	74
sto	35	0	75
0	36	=	76
stop	37	goto	77
sto	38	0	78
1	39	0	79

Initial velocity u

Acceleration a

After time t, velocity $v = u + at$

distance travelled $s = ut + \frac{1}{2}at^2$

Average velocity over the time:

$v_{av} = \frac{1}{2}(u + v)$

$s = v_{av}t$

$v^2 = u^2 + 2as$

(a) Pre-execution:

goto/0/1/u/run/a/run

Execution:

(i) t/run/v/run/s

(ii) goto/4/1/s/run/v

It is not necessary to repeat the pre-execution to repeat (i) or (ii).

(b) Pre-execution:

goto/3/5/u/run/a/run

Execution:

(i) s/run/v

or (ii)goto/0/7/t/run/v/run/s

It is not necessary to repeat the pre-execution to repeat (i) or (ii)

(c) Pre-execution:

goto/5/5/v/run/u/run/v_{av}

Execution:

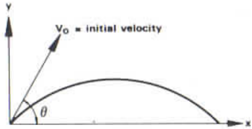
(i) t/run/a/run

(ii) a/run/t/run/s

(iii) s/run/run/a

It is necessary to repeat the pre-execution to repeat (i), (ii) or (iii).

PROJECTILES



v_0 = initial velocity
v = velocity
θ = angle of projection

After time t,

$x = v_0 t \cos\theta$
$y = v_0 t \sin\theta - \frac{1}{2}gt^2$
$v^2 = v_0^2 + g^2t^2 - 2gv_0 t \sin\theta$

Pre-execution:

(a) goto/0/1/g/run/θ/run/v_0/run
(b) goto/6/6/run/θ/run/v_0/run

(Pre-execution (b) enters S.I. standard gravity.)

Execution:

t/run/x/run/y/run/v

It is not necessary to repeat the pre-execution to continue with the execution.

KEY	#	KEY	#
HALT	00	×	40
sto	01	rcl	41
0	02	3	42
stop	03	×	43
sto	04	(	44
1	05	−	45
stop	06	(	46
sto	07	2	47
2	08	×	48
stop	09	rcl	49
sto	10	2	50
3	11	×	51
×	12	rcl	52
rcl	13	1	53
2	14	sin	54
×	15	)	55
rcl	16	)	56
1	17	+	57
cos	18	rcl	58
=	19	2	59
stop	20	x^2	60
×	21	=	61
rcl	22	$\sqrt{x}$	62
1	23	goto	63
tan	24	0	64
−	25	9	65
(	26	C	66
rcl	27	9	67
0	28	./EE	68
÷	29	8	69
2	30	0	70
×	31	6	71
rcl	32	6	72
3	33	5	73
x^2	34	sto	74
)	35	0	75
=	36	goto	76
stop	37	0	77
rcl	38	3	78
0	39		79

KEY	#	KEY	#
HALT	00	÷	40
sto	01	stop	41
1	02	x^2	42
stop	03	=	43
sto	04	arc	44
2	05	sin	45
sin	06	÷	46
×	07	2	47
2	08	—	48
×	09	stop	49
rcl	10	9	50
1	11	0	51
÷	12	=	52
rcl	13	+/—	53
0	14	stop	54
=	15	goto	55
stop	16	3	56
x^2	17	7	57
÷	18	C	58
8	19	9	59
×	20	./EE	60
rcl	21	8	61
0	22	0	62
=	23	6	63
stop	24	6	64
×	25	5	65
4	26	sto	66
×	27	0	67
rcl	28	goto	68
2	29	0	69
tan	30	1	70
1/x	31		71
=	32		72
stop	33		73
goto	34		74
0	35		75
1	36		76
×	37		77
rcl	38		78
0	39		79

PROJECTILES -RANGE, HEIGHT AND FLIGHT TIME

Range, R $= \dfrac{v_0^2 \sin 2\theta}{g}$

Maximum height attained, $H = \dfrac{v_0^2 \sin \theta}{2g}$

Time of flight, $T = \dfrac{2v_0 \sin \theta}{g}$

For a given range and a given speed of projection, two angles of projection θ_0, θ_1 are possible. Error will be returned if none is possible.

Pre-execution:

(a) goto/5/8/run (assumes S.I. standard gravity)

(b) g/sto/0

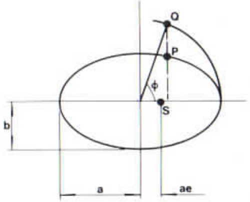
Execution:

(i) goto/0/1/v_0/run/θ/run/ T/run/ H/run/ R

(ii) goto/3/7/R/run/v_0/run/ θ_0/ run/ θ_1

To repeat (i) or (ii) it is not necessary to start with the /goto/.

PLANETARY MOTION



The orbit is an ellipse with the sun at one focus. The position of a planet in its orbit at time t is found by Kepler's equation:

$$\phi - \epsilon \sin \phi = nt$$

ϕ is the eccentric anomaly, i.e. the angle made by a radius from the centre of the ellipse to a point Q, where Q lies on a circle of radius a concentric with the ellipse and the planet P lies on the normal from Q to the major axis of the ellipse.

$\epsilon^2 = 1 - \frac{b^2}{a^2}$, ϵ is the eccentricity of the orbit.

$$n = \sqrt{\frac{G(M+m)}{a^3}}$$

where:

G = gravitational constant
M = mass of sun
m = mass of planet
a = semi major axis
b = semi minor axis

KEY	#	KEY	#
HALT	00	(	40
sto	01	rcl	41
2	02	2	42
×	03	×	43
rcl	04	rcl	44
0	05	0	45
+	06	)	46
rcl	07	−	47
1	08	rcl	48
=	09	5	49
sto	10	=	50
4	11	gin	51
rcl	12	6	52
2	13	5	53
×	14	+/−	54
rcl	15	gin	55
0	16	7	56
−	17	2	57
rcl	18	rcl	58
1	19	5	59
=	20	arc	60
sto	21	D ▶ R	61
3	22	goto	62
rcl	23	0	63
4	24	0	64
+	25	rcl	65
rcl	26	5	66
3	27	sto	67
÷	28	4	68
2	29	goto	69
=	30	2	70
sto	31	3	71
5	32	rcl	72
arc	33	5	73
D ▶ R	34	goto	74
sin	35	2	75
×	36	1	76
rcl	37		77
1	38		78
+	39		79

Pre-execution:

store n and ϵ in memories 0 and 1 respectively.

Execution:

t/run/ϕ°

(note: $\phi = 0$ at first perihelion)

Warning: this program may take some minutes to run.
If no answer appears after 10 minutes:
rcl/5/arc/D ▶ R/ϕ°

PERIOD AND APSIDES OF AN ORBIT

Period, $T = 2\pi\sqrt{\dfrac{a^3}{G(M+m)}}$

Apsidal distances

$= a(1+\epsilon), a(1-\epsilon)$

Execution:

(a) goto/0/1/a/run/G(M + m)/run/T

(b) goto/1/6/T/run/G(M + m)/run/a

KEY	#	KEY	#
HALT	00		40
y^x	01		41
3	02		42
÷	03		43
stop	04		44
=	05		45
$\sqrt{x}$	06		46
×	07		47
2	08		48
×	09		49
π	10		50
=	11		51
goto	12		52
0	13		53
0	14		54
stop	15		55
÷	16		56
2	17		57
÷	18		58
π	19		59
=	20		60
x^2	21		61
×	22		62
stop	23		63
y^x	24		64
(	25		65
3	26		66
1/x	27		67
)	28		68
=	29		69
goto	30		70
1	31		71
5	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00	stop	40
sto	01	÷	41
0	02	stop	42
+	03	+/−	43
stop	04	=	44
÷	05	sto	45
(	06	1	46
rcl	07	stop	47
0	08	×	48
−	09	rcl	49
stop	10	1	50
)	11	+	51
×	12	rcl	52
stop	13	0	53
=	14	=	54
stop	15	goto	55
goto	16	4	56
0	17	7	57
1	18		58
sto	19		59
0	20		60
−	21		61
stop	22		62
÷	23		63
(	24		64
rcl	25		65
0	26		66
+	27		67
stop	28		68
)	29		69
×	30		70
stop	31		71
=	32		72
stop	33		73
goto	34		74
1	35		75
9	36		76
sto	37		77
0	38		78
+	39		79

DOPPLER EFFECT (NON-RELATIVISTIC)

v_o = observer velocity
v_s = source velocity
f_s = transmitted frequency
f_o = observed frequency
c = velocity of wave

$$f_s = \frac{c + v_o}{c - v_s} f_o$$

(a) finds f_s, (b) finds f_o, (c) finds v_s.

(a) Execution:

goto/0/1/c/run/v_o/run/v_s/run/f_o/run/f_s

(b) Execution:

goto/1/9/c/run/v_s/run/v_o/run/f_s/run/f_o

(c) Pre-execution:

goto/3/7/c/v_o/run/f_s/run

Execution:

f_o/run/v_s

It is not necessary to repeat the pre-execution to repeat the execution.

To repeat (a), (b) or (c) it is not necessary to re-enter the /goto/.

COMPOUND PENDULUM

O = point of suspension
G = centre of gravity
r = distance OG
k_O = radius of gyration about O
k_G = radius of gyration about G
ℓ = length of equivalent simple pendulum
T = period

$$\ell = \frac{k_O^2}{r}$$

$$k_O^2 = k_G^2 + r^2$$

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

Execution:

(a) goto/0/7/ℓ/run/T
(b) goto/3/7/T/run/ℓ
(c) goto/2/5/r/run/k_G/run/ℓ/run/T
(d) goto/0/1/r/run/k_O/run/ℓ/run/T

Executions (a) and (b) can be used for a simple pendulum.

KEY	#	KEY	#
HALT	00	π	40
1/x	01	=	41
×	02	x^2	42
stop	03	×	43
x^2	04	9	44
=	05	./EE	45
stop	06	8	46
÷	07	0	47
9	08	6	48
./EE	09	6	49
8	10	5	50
0	11	=	51
6	12	goto	52
6	13	0	53
5	14	0	54
=	15		55
$\sqrt{x}$	16		56
×	17		57
2	18		58
×	19		59
π	20		60
=	21		61
goto	22		62
0	23		63
0	24		64
÷	25		65
(	26		66
x^2	27		67
+	28		68
stop	29		69
x^2	30		70
)	31		71
x◀▶y	32		72
=	33		73
goto	34		74
0	35		75
6	36		76
÷	37		77
2	38		78
÷	39		79

30. CENTRE OF GRAVITY AND RADIUS GYRATION

In the programs

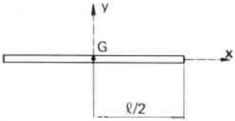
G = position of centre of gravity

k_{xx} = radius of gyration about x–axis

k_{yy} = radius of gyration about y–axis

k_{zz} = radius of gyration about z–axis

STRAIGHT ROD



$k_{xx}^2 = 0$

$k_{zz}^2 = k_{yy}^2 = \frac{\ell^2}{12}$

Execution:

ℓ/run/k_{yy}^2

Example:

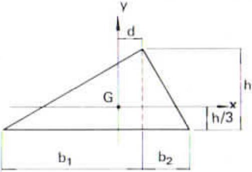
ℓ = 10/run/8.3333333

so k_{yy}^2 = 8.3333333

KEY	#	KEY	#
HALT	00		40
x^2	01		41
÷	02		42
1	03		43
2	04		44
=	05		45
goto	06		46
0	07		47
0	08		48
	09		49
	10		50
	11		51
	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

TRI–ANGULAR LAMINAR

KEY	#	KEY	#
HALT	00	x^2	40
sto	01	÷	41
0	02	1	42
stop	03	8	43
sto	04	=	44
1	05	goto	45
stop	06	0	46
sto	07	0	47
2	08		48
rcl	09		49
0	10		50
–	11		51
rcl	12		52
1	13		53
÷	14		54
3	15		55
=	16		56
stop	17		57
rcl	18		58
0	19		59
x^2	20		60
+	21		61
rcl	22		62
1	23		63
x^2	24		64
+	25		65
(	26		66
rcl	27		67
0	28		68
×	29		69
rcl	30		70
1	31		71
)	32		72
÷	33		73
1	34		74
8	35		75
=	36		76
stop	37		77
rcl	38		78
2	39		79



$$d = \frac{b_1 - b_2}{3}$$

$$k_{xx}^2 = \frac{h^2}{18}$$

$$k_{yy}^2 = \frac{b_1^2 + b_1 b_2 + b_2^2}{18}$$

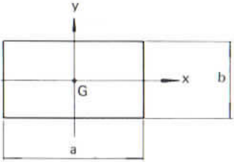
Execution:

b_1/run/b_2/run/h
run/d/run/k_{yy}^2/run/k_{xx}^2

Example:

$b_1 = 100$
$b_2 = h = 10$
$d = 30$
$k_{yy}^2 = 616.66667$
$k_{xx}^2 = 5.5555556$

RECT-ANGULAR LAMINAR



$$k_{xx}^2 = \frac{b^2}{12}$$

$$k_{yy}^2 = \frac{a^2}{12}$$

Execution:

b/run/k_{xx}^2/a/run/k_{yy}^2

Example:

b = a = 10

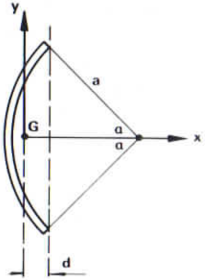
k_{xx}^2 = 8.3333333

k_{yy}^2 = 8.3333333

KEY	#	KEY	#
HALT	00		40
x^2	01		41
÷	02		42
1	03		43
2	04		44
=	05		45
goto	06		46
0	07		47
0	08		48
	09		49
	10		50
	11		51
	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

CIRCULAR ROD

KEY	#	KEY	#
HALT	00	1	40
sto	01	x^2	41
0	02	=	42
stop	03	stop	43
sto	04	rcl	44
1	05	0	45
×	06	sin	46
(	07	×	47
rcl	08	rcl	48
0	09	0	49
sin	10	cos	50
÷	11	÷	51
rcl	12	rcl	52
0	13	0	53
D ▶ R	14	D ▶ R	54
−	15	+	55
rcl	16	1	56
0	17	÷	57
cos	18	2	58
)	19	−	59
=	20	(	60
stop	21	rcl	61
rcl	22	0	62
0	23	sin	63
sin	24	x^2	64
×	25	÷	65
rcl	26	rcl	66
0	27	0	67
cos	28	D ▶ R	68
+/−	29	x^2	69
÷	30	)	70
rcl	31	×	71
0	32	rcl	72
D ▶ R	33	1	73
+	34	x^2	74
1	35	=	75
−	36	goto	76
2	37	0	77
×	38	0	78
rcl	39		79



$$d = a\,\frac{\sin\alpha - \alpha\cos\alpha}{\alpha}$$

$$k_{xx}^2 = \frac{a^2}{2\alpha}(\alpha - \sin\alpha\cos\alpha)$$

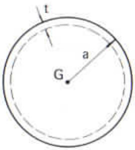
$$k_{yy}^2 = \frac{a^2}{2\alpha^2}\,[\alpha(\alpha + \sin\alpha\cos\alpha) - 2\sin^2\alpha]$$

Execution:

α/run/a/run/d/run/k_{xx}^2/run/k_{yy}^2

Enter α in degrees.
N.B. The formulae are valid *only* when α is measured in radians. The program takes this into account.

SPHERICAL SHELL



Radius a

Thickness t

$k^2_{xx} = k^2_{yy} = k^2_{zz}$

$= \frac{2a^2}{3}$

Volume $= 4\pi a^2 t$

Execution:

a/run/k^2_{xx}/t/run/volume

Example:

$a = t = 10$

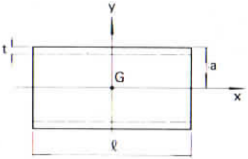
$k^2_{xx} = 66.666667$

vol $= 12566.371$

KEY	#	KEY	#
HALT	00		40
x^2	01		41
×	02		42
2	03		43
÷	04		44
3	05		45
×	06		46
stop	07		47
×	08		48
6	09		49
×	10		50
π	11		51
=	12		52
goto	13		53
0	14		54
0	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

THIN WALLED CIRCULAR SECTION TUBE

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
sto	04		44
1	05		45
stop	06		46
×	07		47
rcl	08		48
1	09		49
×	10		50
rcl	11		51
0	12		52
×	13		53
2	14		54
×	15		55
π	16		56
=	17		57
stop	18		58
rcl	19		59
0	20		60
x^2	21		61
stop	22		62
÷	23		63
2	24		64
+	25		65
(	26		66
rcl	27		67
1	28		68
x^2	29		69
÷	30		70
1	31		71
2	32		72
)	33		73
=	34		74
goto	35		75
0	36		76
0	37		77
	38		78
	39		79



Volume $= 2\pi a \ell t$

$k^2_{xx} = a^2$

$k^2_{yy} = k^2_{zz} = \frac{a^2}{2} + \frac{\ell^2}{12}$

Execution:

a/run/ℓ/run/t/run/volume/run/k^2_{xx}/run/k^2_{yy}

Example:

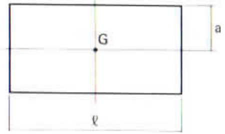
$a = \ell = t = 10$

vol = 6283.1854

k^2_{xx} = 100

k^2_{yy} = 58.333333

SOLID CYLINDER



$$k_{xx}^2 = \frac{a^2}{2}$$

$$k_{zz}^2 = k_{yy}^2 = \frac{a^2}{4} + \frac{\ell^2}{12}$$

$$\text{volume} = \pi a^2 \ell$$

Execution:

a/run/ℓ/run/volume/run/k_{xx}^2/run/k_{yy}^2

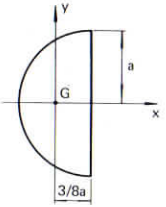
Example:

a = 10, ℓ = 10
volume = 3141.5927
k_{xx}^2 = 50
k_{yy}^2 = 33.333333

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
sto	04		44
1	05		45
×	06		46
rcl	07		47
0	08		48
x^2	09		49
×	10		50
π	11		51
=	12		52
stop	13		53
rcl	14		54
0	15		55
x^2	16		56
÷	17		57
2	18		58
=	19		59
stop	20		60
÷	21		61
2	22		62
+	23		63
(	24		64
rcl	25		65
1	26		66
x^2	27		67
÷	28		68
1	29		69
2	30		70
)	31		71
=	32		72
goto	33		73
0	34		74
0	35		75
	36		76
	37		77
	38		78
	39		79

SOLID HEMISPHERE

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
x^2	03		43
×	04		44
rcl	05		45
0	06		46
×	07		47
2	08		48
×	09		49
π	10		50
÷	11		51
3	12		52
=	13		53
stop	14		54
rcl	15		55
0	16		56
x^2	17		57
×	18		58
2	19		59
÷	20		60
5	21		61
=	22		62
stop	23		63
rcl	24		64
0	25		65
x^2	26		66
×	27		67
8	28		68
3	29		69
÷	30		70
3	31		71
2	32		72
0	33		73
=	34		74
goto	35		75
0	36		76
0	37		77
	38		78
	39		79



$$Vol = \frac{2\pi a^3}{3}$$

$$k^2_{xx} = \frac{2a^2}{5}$$

$$k^2_{zz} = k^2_{yy} = \frac{83a^2}{320}$$

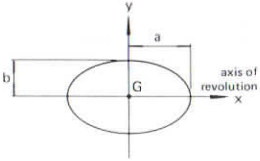
Execution:

a/run/volume/run/k^2_{xx}/run/k^2_{yy}

Example:

$a = 10$
vol = 2094.395
$k^2_{xx} = 40$
$k^2_{yy} = 25.9375$

SOLID SPHEROID



$$\text{Volume} = \frac{4\pi ab^2}{3}$$

$$k_{xx}^2 = \frac{2b^2}{5}$$

$$k_{zz}^2 = k_{yy}^2 = \frac{a^2 + b^2}{5}$$

Execution:

a/run/b/run/volume/run/k_{xx}^2/run/k_{yy}^2

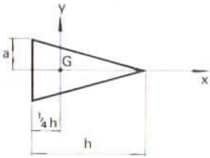
Example:

a = 10, b = 10
vol = 4188.78
k_{xx}^2 = 40
k_{yy}^2 = 40

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
sto	04		44
1	05		45
x^2	06		46
×	07		47
rcl	08		48
0	09		49
×	10		50
π	11		51
×	12		52
4	13		53
÷	14		54
3	15		55
=	16		56
stop	17		57
rcl	18		58
1	19		59
x^2	20		60
×	21		61
2	22		62
÷	23		63
5	24		64
=	25		65
stop	26		66
rcl	27		67
0	28		68
x^2	29		69
+	30		70
rcl	31		71
1	32		72
x^2	33		73
÷	34		74
5	35		75
=	36		76
goto	37		77
0	38		78
0	39		79

SOLID CONE

KEY	#	KEY	#
HALT	00	0	40
sto	01	0	41
0	02		42
stop	03		43
sto	04		44
1	05		45
×	06		46
rcl	07		47
0	08		48
x^2	09		49
×	10		50
π	11		51
÷	12		52
3	13		53
=	14		54
stop	15		55
rcl	16		56
0	17		57
x^2	18		58
×	19		59
./EE	20		60
3	21		61
=	22		62
stop	23		63
rcl	24		64
0	25		65
x^2	26		66
×	27		67
4	28		68
+	29		69
rcl	30		70
1	31		71
x^2	32		72
×	33		73
3	34		74
÷	35		75
8	36		76
0	37		77
=	38		78
goto	39		79



$$\text{Vol} = \frac{\pi a^2 h}{3}$$

$$k_{xx}^2 = \frac{3a^2}{10}$$

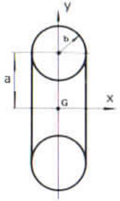
$$k_{zz}^2 = k_{yy}^2 = \frac{3(4a^2 + h^2)}{80}$$

Execution:

a/run/h/run/ vol/run/ k_{xx}^2/run/ k_{yy}^2

TOROID

30.11



Volume $= 2\pi ab^2$

$k^2_{xx} = a^2 + \frac{3b^2}{4}$

$k^2_{zz} = k^2_{yy} = \frac{a^2}{2} + \frac{5b^2}{8}$

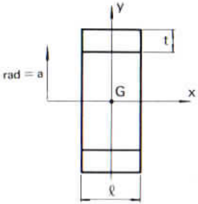
Execution:

a/run/b/run/vol/run/k^2_{xx}/run/k^2_{yy}

KEY	#	KEY	#
HALT	00	0	40
sto	01	x^2	41
0	02	÷	42
stop	03	2	43
sto	04	=	44
1	05	goto	45
x^2	06	0	46
×	07	0	47
rcl	08		48
0	09		49
×	10		50
π	11		51
x^2	12		52
×	13		53
2	14		54
=	15		55
stop	16		56
rcl	17		57
1	18		58
x^2	19		59
×	20		60
./EE	21		61
7	22		62
5	23		63
+	24		64
rcl	25		65
0	26		66
x^2	27		67
=	28		68
stop	29		69
rcl	30		70
1	31		71
x^2	32		72
×	33		73
1	34		74
./EE	35		75
2	36		76
5	37		77
+	38		78
rcl	39		79

KEY	#	KEY	#
HALT	00	x^2	40
sto	01	÷	41
0	02	1	42
stop	03	2	43
sto	04	)	44
1	05	=	45
stop	06	goto	46
sto	07	0	47
2	08	0	48
×	09		49
rcl	10		50
0	11		51
×	12		52
rcl	13		53
1	14		54
×	15		55
π	16		56
×	17		57
2	18		58
=	19		59
stop	20		60
rcl	21		61
0	22		62
x^2	23		63
+	24		64
(	25		65
rcl	26		66
1	27		67
x^2	28		68
÷	29		69
4	30		70
)	31		71
=	32		72
stop	33		73
÷	34		74
2	35		75
+	36		76
(	37		77
rcl	38		78
2	39		79

TOROID OF RECTANGULAR SECTION



$$\text{vol} = 2\pi a t \ell$$

$$k_{xx}^2 = a^2 + \frac{t^2}{4}$$

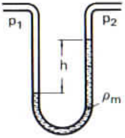
$$k_{zz}^2 = k_{yy}^2 = \frac{a^2}{2} + \frac{t^2}{8} + \frac{\ell^2}{12}$$

Execution:

a/run/t/run/ℓ/run/vol/run/k_{xx}^2/run/k_{yy}^2

31. FLUID MECHANICS

MANOMETER



$p_1 - p_2 = gh(\rho_m - \rho)$

Execution:

ρ_m/run/ρ/run/h/run/pressure diff

KEY	#	KEY	#
HALT	00		40
—	01		41
stop	02		42
×	03		43
stop	04		44
×	05		45
9	06		46
./EE	07		47
8	08		48
0	09		49
6	10		50
6	11		51
5	12		52
=	13		53
goto	14		54
0	15		55
0	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

PITOT STATIC TUBE

KEY	#	KEY	#
HALT	00		40
−	01		41
stop	02		42
×	03		43
2	04		44
÷	05		45
stop	06		46
=	07		47
$\sqrt{x}$	08		48
goto	09		49
0	10		50
0	11		51
	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

u = velocity of fluid
P = total pressure
p = static pressure
ρ = density

$$u = \sqrt{\frac{2(P-p)}{\rho}}$$

Execution:

P/run/p/run/ρ/run/u

SHARP EDGED ORIFICE

A = area
Q = volume flow rate
C_d = discharge coefficient
$Q = AC_d\sqrt{2gh}$

Execution:

h/run/C_d/run/A/run/Q

KEY	#	KEY	#
HALT	00		40
×	01		41
1	02		42
9	03		43
./EE	04		44
6	05		45
1	06		46
3	07		47
3	08		48
=	09		49
$\sqrt{x}$	10		50
×	11		51
stop	12		52
×	13		53
stop	14		54
=	15		55
goto	16		56
0	17		57
0	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

VENTURI

KEY	#	KEY	#
HALT	00		40
÷	01		41
stop	02		42
=	03		43
x^2	04		44
—	05		45
1	06		46
×	07		47
stop	08		48
=	09		49
1/x	10		50
×	11		51
2	12		52
×	13		53
(	14		54
stop	15		55
—	16		56
stop	17		57
)	18		58
=	19		59
$\sqrt{x}$	20		60
goto	21		61
0	22		62
0	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

p_1 = static pressure in tube
p_2 = static pressure in throat
a_1 = cross sectional area of tube
a_2 = cross sectional area of throat
u = velocity of fluid
ρ = density

$$u = \sqrt{\frac{2(p_1 - p_2)}{\rho\left(\frac{a_1^2}{a_2^2} - 1\right)}}$$

Execution:

a_1/run/a_2/run/ρ/run/p_1/run/p_2/run/u

PIPE FLOW

L = length
D = diameter
C_f = skin inertia coefficient
ρ = density
U_m = mean velocity

$$\text{Pressure drop} = 2\frac{L}{D}C_f\rho U_m^2$$

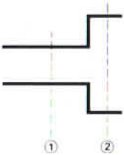
Execution:

U_m/run/ρ/run/C_f/run/L/run/D/run/pressure drop

KEY	#	KEY	#
HALT	00		40
x^2	01		41
×	02		42
stop	03		43
×	04		44
stop	05		45
×	06		46
stop	07		47
÷	08		48
stop	09		49
×	10		50
2	11		51
=	12		52
goto	13		53
0	14		54
0	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

PIPE FLOW (SUDDEN EXPANSION)

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
−	03		43
stop	04		44
=	05		45
x^2	06		46
÷	07		47
1	08		48
9	09		49
./EE	10		50
6	11		51
1	12		52
3	13		53
3	14		54
=	15		55
stop	16		56
÷	17		57
stop	18		58
+/−	19		59
+	20		60
1	21		61
=	22		62
x^2	23		63
×	24		64
rcl	25		65
0	26		66
x^2	27		67
÷	28		68
1	29		69
9	30		70
./EE	31		71
6	32		72
1	33		73
3	34		74
3	35		75
=	36		76
goto	37		77
0	38		78
0	39		79



$$\text{head loss} = \frac{(u_1 - u_2)^2}{2g}$$

$$\Delta h = \frac{u_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$$

Execution:

u_1/run/u_2/run/head loss/A_1/run/A_2/run/Δh

IDEAL PRESSURE RISE DIFFUSER

$$\Delta p = \frac{\rho u_1^2}{2}\left(1 - \frac{A_1^2}{A_1^2}\right)$$

Execution:

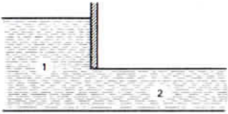
A_1/run/A_2/run/u_1/run/ρ/run/Δp

$A_2 > A_1$

KEY	#	KEY	#
HALT	00		40
÷	01		41
stop	02		42
=	03		43
x^2	04		44
+/−	05		45
+	06		46
1	07		47
×	08		48
stop	09		49
x^2	10		50
×	11		51
stop	12		52
÷	13		53
2	14		54
=	15		55
goto	16		56
0	17		57
0	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

SLUICE GATE

KEY	#	KEY	#
HALT	00	x^2	40
sto	01	÷	41
0	02	stop	42
stop	03	÷	43
sto	04	9	44
1	05	./EE	45
+	06	8	46
rcl	07	0	47
0	08	6	48
×	09	6	49
rcl	10	5	50
1	11	=	51
=	12	stop	52
1/x	13	goto	53
×	14	4	54
rcl	15	0	55
0	16		56
x^2	17		57
×	18		58
2	19		59
=	20		60
goto	21		61
0	22		62
0	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



$$F_2^2 = \frac{2h_1^2}{h_2(h_1 + h_2)}$$

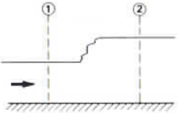
$$= \frac{u_2^2}{gh_2}$$

Execution:

(a) h_1/run/h_2/run/F_2^2

(b) goto/4/0/u_2/run/h_2/run/F_2^2

HYDRAULIC JUMP



$$F_1^2 = \frac{h_2(h_1 + h_2)}{2h_1^2}$$

$$F_2^2 = \frac{h_1(h_1 + h_2)}{2h_2^2}$$

Execution:

(a) h_2/run/h_1/run/F_2^2
(b) h_1/run/h_2/run/F_1^2

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
+	03		43
stop	04		44
sto	05		45
1	06		46
×	07		47
rcl	08		48
1	09		49
÷	10		50
rcl	11		51
0	12		52
x^2	13		53
÷	14		54
2	15		55
=	16		56
goto	17		57
0	18		58
0	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

COM– PRESSIBLE FLOW

KEY	#	KEY	#
HALT	00		40
x^2	01		41
×	02		42
(	03		43
stop	04		44
sto	05		45
0	06		46
—	07		47
1	08		48
)	09		49
÷	10		50
2	11		51
+/—	12		52
+	13		53
1	14		54
=	15		55
stop	16		56
y^x	17		57
(	18		58
rcl	19		59
0	20		60
—	21		61
1	22		62
=	23		63
1/x	24		64
×	25		65
rcl	26		66
0	27		67
)	28		68
=	29		69
stop	30		70
y^x	31		71
rcl	32		72
0	33		73
1/x	34		74
=	35		75
goto	36		76
0	37		77
0	38		78
	39		79

Perfect gas relationships:

M = mach number

γ = ratio of specific heats = 1.405 for dry air.

$$\frac{T}{T_0} = \left(1 - \frac{(\gamma - 1)M^2}{2}\right)$$

$$\frac{P}{P_0} = \left(1 - \frac{(\gamma - 1)M^2}{2}\right)^{\gamma/\gamma-1}$$

$$\frac{\rho}{\rho_0} = \left(1 - \frac{(\gamma - 1)M^2}{2}\right)^{1/\gamma-1}$$

Execution:

M/run/γ/run/$\frac{T}{T_0}$/run/$\frac{P}{P_0}$/run/$\frac{\rho}{\rho_0}$

32. RELATIVITY

LORENTZ TRANSFORMATION

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Execution:

v/run/x/run/t/
run/x'/run/t'/
new x/run/new t/run/
new x'/run/new t'
. . .

To change v:
goto/0/1
To enter standard c:
goto/6/7/run
To enter own c:
goto/7/8/c/run

KEY	#	KEY	#
HALT	00	rcl	40
÷	01	1	41
rcl	02	×	42
0	03	rcl	43
=	04	3	44
sto	05	÷	45
1	06	rcl	46
x^2	07	0	47
+/−	08	)	48
+	09	×	49
1	10	rcl	50
=	11	2	51
$\sqrt{x}$	12	=	52
1/x	13	goto	53
sto	14	1	54
2	15	6	55
stop	16		56
sto	17		57
3	18		58
−	19		59
(	20		60
rcl	21		61
1	22		62
×	23		63
rcl	24		64
0	25		65
×	26		66
stop	27	C	67
sto	28	2	68
4	29	./EE	69
)	30	9	70
×	31	9	71
rcl	32	7	72
2	33	9	73
=	34	2	74
stop	35	5	75
rcl	36	./EE	76
4	37	8	77
−	38	sto	78
(	39	0	79

KEY	#	KEY	#
HALT	00		40
÷	01		41
rcl	02		42
0	03		43
=	04		44
x^2	05		45
+/−	06		46
+	07		47
1	08		48
=	09		49
$\sqrt{x}$	10		50
sto	11		51
1	12		52
stop	13		53
rcl	14		54
1	15		55
=	16		56
goto	17		57
0	18		58
0	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

FITZ-GERALD CON-TRACTION, TIME DILATION AND MASS CHANGE

$$T' = T\left(1 - \frac{v^2}{c^2}\right)^{1/2}$$

$$L' = L\left(1 - \frac{v^2}{c^2}\right)^{1/2}$$

$$M' = M\left(1 - \frac{v^2}{c^2}\right)^{-1/2}$$

Pre-execution:

Store c in memory 0

Execution:

(i) v/run/T/×/run/ T′
(ii) v/run/T′/÷/run/ T
(iii) v/run/L/×/run/ L′
(iv) v/run/L′/÷/run/ L
(v) v/run/M/÷/run/ M′
(vi) v/run/M′/×/run/ M

RELATIVISTIC DOPPLER EFFECT

f_s = source frequency
f_0 = observed frequency
c = 2.997925×10^8 ms^{-1}
v = speed of source (relative to observer)
θ = direction of motion of source relative to observer

$$f_0 = \frac{f_s \sqrt{1 - \frac{v^2}{c^2}}}{1 - \frac{v}{c}\cos\theta}$$

Execution:

(a) v/run/θ/run/f_s/×/run/f_0
(b) v/run/θ/run/f_0/÷/run/f_s

After (a) to find new f_0 given old v, θ and new f_s:
f_s/=/f_0

After (b) to find new f_s given old v, θ and new f_0:
f_0/=/f_s

KEY	#	KEY	#
HALT	00	3	40
÷	01	5	41
2	02		42
./EE	03		43
9	04		44
9	05		45
7	06		46
9	07		47
2	08		48
5	09		49
./EE	10		50
8	11		51
=	12		52
sto	13		53
0	14		54
x^2	15		55
+/−	16		56
+	17		57
1	18		58
=	19		59
$\sqrt{x}$	20		60
÷	21		61
(	22		62
stop	23		63
cos	24		64
×	25		65
rcl	26		66
0	27		67
+/−	28		68
+	29		69
1	30		70
)	31		71
=	32		72
sto	33		73
0	34		74
stop	35		75
rcl	36		76
0	37		77
=	38		78
goto	39		79

KEY	#	KEY	#
HALT	00	÷	40
÷	01	stop	41
rcl	02	=	42
0	03	x^2	43
—	04	—	44
1	05	1	45
÷	06	÷	46
(	07	(	47
+	08	+	48
2	09	2	49
)	10	)	50
+/—	11	+/—	51
=	12	×	52
$\sqrt{x}$	13	rcl	53
sto	14	0	54
1	15	=	55
stop	16	stop	56
rcl	17	goto	57
1	18	4	58
=	19	0	59
goto	20		60
0	21		61
0	22		62
	23		63
	24		64
	25		65
	26		66
	27	C	67
	28	2	68
	29	./EE	69
	30	9	70
	31	9	71
	32	7	72
	33	9	73
	34	2	74
	35	5	75
	36	./EE	76
	37	8	77
	38	sto	78
	39	0	79

RED SHIFT AND BLUE SHIFT

Relativistic Doppler effect with source moving away from observer, with velocity v

$$f_0 = f_s \sqrt{\frac{1-\frac{v}{c}}{1+\frac{v}{c}}}$$

Pre-execution:

For S.I. units:
goto/6/7/run

For own value of c:
goto/7/8/c/run

This pre-execution need not be repeated.

Execution:

(a) v/run/c/run/f_s/×/run/ f_0
(b) v/run/c/run/f_0/÷/run/ f_s
(c) goto/4/0/f_0/run/f_s/run/ v
(d) goto/4/0/λ_s/run/λ_0/run/ v

Where λ_0; λ_s are the wavelengths corresponding to frequencies f_0 ; f_s.

RELATIVISTIC MASS AND OBSERVED VELOCITY OF AN ACCELERATED ELECTRON OR ION

m = rest mass (9.1096×10^{-31} kg for electron)

e = charge (1.6022×10^{-19} for electron)

c = speed of light

V = accelerating potential (volts)

$$M_r = m\left(1 + \frac{eV}{mc^2}\right)$$

$$V_r = c\sqrt{1 - \left(1 + \frac{eV}{mc^2}\right)^{-2}}$$

Pre-execution:

Store m, e, c in memories 0, 1, 2 respectively.

Execution:

V/run/M_r/run/V_r

KEY	#	KEY	#
HALT	00		40
×	01		41
rcl	02		42
1	03		43
÷	04		44
rcl	05		45
0	06		46
÷	07		47
rcl	08		48
2	09		49
x^2	10		50
+	11		51
1	12		52
=	13		53
sto	14		54
3	15		55
×	16		56
rcl	17		57
0	18		58
=	19		59
stop	20		60
rcl	21		61
3	22		62
x^2	23		63
1/x	24		64
+/−	25		65
+	26		66
1	27		67
=	28		68
$\sqrt{x}$	29		69
×	30		70
rcl	31		71
2	32		72
=	33		73
goto	34		74
0	35		75
0	36		76
	37		77
	38		78
	39		79

DEFLECTION OF A RELATIVISTIC ELECTRON OR ION BY A SMALL TRANSVERSE FIELD

KEY	#	KEY	#
HALT	00		40
×	01		41
rcl	02		42
0	03		43
+	04		44
1	05		45
÷	06		46
(	07		47
x^2	08		48
—	09		49
1	10		50
)	11		51
×	12		52
rcl	13		53
0	14		54
×	15		55
stop	16		56
=	17		57
arc	18		58
tan	19		59
goto	20		60
0	21		61
0	22		62
÷	23		63
stop	24		64
÷	25		65
stop	26		66
x^2	27		67
=	28		68
sto	29		69
0	30		70
goto	31		71
0	32		72
0	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

Field F
Energy eV
Deflection θ

$$\tan\theta \simeq \frac{\frac{eF}{mc^2}\left(1+\frac{eV}{mc^2}\right)}{\left(1+\frac{eV}{mc^2}\right)^2-1}$$

Pre-execution:

goto/2/3/e/run/m/run/c/run

Execution:

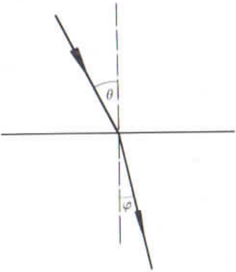
V/run/F/run/$\theta°$

Remember to use a consistent set of units (e.g. S.I.).

33. OPTICS

33.1 Snell's Law
33.2 Total internal reflection
33.3 Simple Lens
33.4 Diffraction grating

SNELL´S LAW



Incident angle = θ
Refractive angle = φ
Relative refractive index =

$$\text{R.I.} = \frac{\sin\theta}{\sin\varphi}$$

Execution:

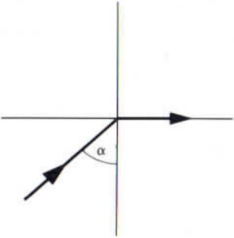
(a) goto/0/1/θ/run/φ/run/R.I.
(b) goto/1/0/R.I./run/φ/run/θ
(c) goto/2/0/R.I./run/θ/run/φ

It is not necessary to repeat the /goto/ to repeat (a), (b) or (c).

KEY	#	KEY	#
HALT	00		40
sin	01		41
÷	02		42
stop	03		43
sin	04		44
=	05		45
goto	06		46
0	07		47
0	08		48
stop	09		49
×	10		50
stop	11		51
sin	12		52
=	13		53
arc	14		54
sin	15		55
goto	16		56
0	17		57
9	18		58
stop	19		59
1/x	20		60
×	21		61
stop	22		62
sin	23		63
=	24		64
arc	25		65
sin	26		66
goto	27		67
1	28		68
9	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

TOTAL INTERNAL REFLECTION

KEY	#	KEY	#
HALT	00		40
sin	01		41
1/x	02		42
goto	03		43
0	04		44
0	05		45
stop	06		46
1/x	07		47
arc	08		48
sin	09		49
goto	10		50
0	11		51
6	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



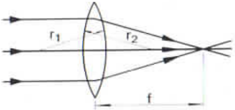
critical angle $= \alpha$
relative refractive index $=$
R.I. > 1

Execution:

(a) goto/0/1/α/run/R.I.
(b) goto/0/7/R.I./run/α

It is not necessary to repeat the /goto/ to repeat (a) or (b).

FOCAL LENGTH OF A SIMPLE SPHERICAL LENS



r_1, r_2 = radii of curvature of lens surfaces.
n = relative refractive index.

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

For concave surfaces take r negative.
For plane surfaces take $r_2 = 10^{99}$
f is negative for a virtual focus.

Execution:

(a) goto/0/1/r_1/run/r_2/run/n/run/f

(b) goto/1/7/f/run/n/run/r_1/run/r_2

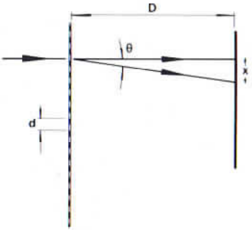
(c) goto/3/3/f/run/r_1/run/r_2/run/n

It is not necessary to repeat the /goto/ to repeat (a), (b) or (c).

KEY	#	KEY	#
HALT	00	1/x	40
1/x	01	)	41
+	02	+	42
stop	03	1	43
1/x	04	=	44
×	05	goto	45
(	06	3	46
stop	07	2	47
—	08		48
1	09		49
)	10		50
=	11		51
1/x	12		52
goto	13		53
0	14		54
0	15		55
stop	16		56
1/x	17		57
÷	18		58
(	19		59
stop	20		60
—	21		61
1	22		62
)	23		63
—	24		64
stop	25		65
1/x	26		66
=	27		67
1/x	28		68
goto	29		69
1	30		70
6	31		71
stop	32		72
1/x	33		73
÷	34		74
(	35		75
stop	36		76
1/x	37		77
+	38		78
stop	39		79

KEY	#	KEY	#
HALT	00		40
÷	01		41
stop	02		42
=	03		43
arc	04		44
tan	05		45
sin	06		46
×	07		47
stop	08		48
÷	09		49
stop	10		50
=	11		51
goto	12		52
0	13		53
0	14		54
stop	15		55
×	16		56
stop	17		57
÷	18		58
stop	19		59
=	20		60
arc	21		61
sin	22		62
tan	23		63
×	24		64
stop	25		65
=	26		66
goto	27		67
1	28		68
5	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

DIFFRACTION GRATING



d = width of slit
D = distance to image
x = displacement of nth order interference fringe
λ = wavelength
θ = angle of diffraction

$$\lambda = \frac{d \sin \theta}{n}$$

$$\tan \theta = \frac{x}{D}$$

Execution:

(a) goto/0/1/x/run/D/run/d/run/n/run/λ

(b) goto/1/6/λ/run/n/run/d/run/D/run/x

It is not necessary to repeat the /goto/ to repeat (a) or (b).

34. ELECTROMECHANICS

CAPACITANCE OF SPHERE, CONCENTRIC SPHERES AND CONCENTRIC CYLINDERS

(i) Sphere of radius a:

$C = 4\pi\epsilon_0\epsilon_r a$

(ii) Concentric spheres of radii a and b, b > a:

$$C = 4\pi\epsilon_0\epsilon_r \frac{ab}{b-a}$$

(iii) Concentric cylinders of radii a and b, b > a, length ℓ:

$$C = 4\pi\epsilon_0\epsilon_r \frac{\ell}{2\ln\left(\frac{b}{a}\right)}$$

Execution:

(i) goto/1/0/a/run/ϵ_r/run/C

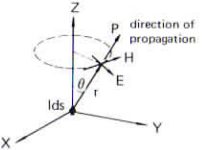
(ii) goto/1/6/a/run/b/run/ϵ_r/run/C

(iii) goto/0/1/a/run/b/run/ℓ/run/ϵ_r/run/C

KEY	#	KEY	#
HALT	00		40
1/x	01		41
×	02		42
stop	03		43
=	04		44
ln	05		45
×	06		46
2	07		47
=	08		48
1/x	09		49
×	10		50
stop	11		51
=	12		52
goto	13		53
2	14		54
2	15		55
1/x	16		56
−	17		57
stop	18		58
1/x	19		59
=	20		60
1/x	21		61
×	22		62
1	23		63
./EE	24		64
1	25		65
1	26		66
2	27		67
6	28		68
5	29		69
./EE	30		70
1	31		71
0	32		72
+/−	33		73
×	34		74
stop	35		75
=	36		76
goto	37		77
0	38		78
0	39		79

KEY	#	KEY	#
HALT	00		40
sin	01		41
÷	02		42
stop	03		43
×	04		44
stop	05		45
÷	06		46
stop	07		47
÷	08		48
2	09		49
=	10		50
stop	11		51
×	12		52
(	13		53
×	14		54
3	15		55
7	16		56
6	17		57
./EE	18		58
7	19		59
3	20		60
=	21		61
stop	22		62
)	23		63
÷	24		64
2	25		65
=	26		66
goto	27		67
0	28		68
0	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

FIELD STRENGTH AND POYNTING VECTOR DUE TO AN ELECTRIC DIPOLE



$$H_{pk} = \frac{Ids}{2\lambda r} \sin\theta$$

$$E_{pk} = \mu_0 c H_{pk}$$

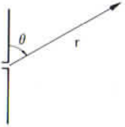
$$P_{av} = \frac{E_{pk} H_{pk}}{2}$$

λ = wavelength

Execution:

θ/run/r/run/Ids/run/λ/run/
H_{pk}/run/E_{pk}/run/P_{av}

RADIATION FROM A HALF WAVE DIPOLE



$$H_{pk} = \frac{I}{2\pi r} \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

$$E_{pk} \simeq 377\ H_{pk}$$

$$P_{av} = \frac{H_{pk}E_{pk}}{2}$$

$$R_r \simeq 79.2\Omega$$

$$P_r = \frac{I^2 R_r}{2}$$

θ in degrees

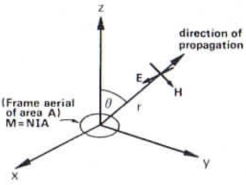
Execution:

I/run/r/run/θ/run/H_{pk}/run/E_{pk}/run/P_{av}/run/P_r

KEY	#	KEY	#
HALT	00	rcl	40
sto	01	1	41
0	02	÷	42
stop	03	2	43
sto	04	=	44
1	05	stop	45
stop	06	rcl	46
sto	07	0	47
2	08	x^2	48
cos	09	×	49
×	10	3	50
9	11	6	51
0	12	./EE	52
=	13	4	53
cos	14	5	54
÷	15	=	55
rcl	16	goto	56
2	17	0	57
sin	18	0	58
×	19		59
rcl	20		60
0	21		61
÷	22		62
rcl	23		63
1	24		64
÷	25		65
2	26		66
÷	27		67
π	28		68
=	29		69
sto	30		70
1	31		71
stop	32		72
×	33		73
3	34		74
7	35		75
7	36		76
=	37		77
stop	38		78
×	39		79

RADIATION FROM LOOP (OR FERRITE) ANTENNA

KEY	#	KEY	#
HALT	00	stop	40
sto	01	rcl	41
0	02	0	42
×	03	×	43
stop	04	rcl	44
sto	05	2	45
1	06	÷	46
×	07	rcl	47
stop	08	3	48
sto	09	=	49
2	10	x^2	50
×	11	×	51
π	12	6	52
÷	13	2	53
stop	14	2	54
x^2	15	9	55
sto	16	8	56
3	17	./EE	57
÷	18	7	58
stop	19	=	59
×	20	stop	60
stop	21	×	61
sin	22	rcl	62
=	23	1	63
stop	24	x^2	64
×	25	÷	65
(	26	2	66
×	27	=	67
3	28	goto	68
7	29	0	69
6	30	0	70
./EE	31		71
7	32		72
3	33		73
=	34		74
stop	35		75
)	36		76
÷	37		77
2	38		78
=	39		79



$$H_{pk} = \frac{NIA}{\lambda^2 r} \pi \sin\theta$$

$$E_{pk} = \mu_0 c H_{pk}$$

$$P_{av} = \frac{H_{pk} E_{pk}}{2}$$

For Ferrite replace NIA by NIA μ_{eff}

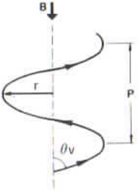
$$R_r = \left(\frac{NA}{\lambda^2}\right)^2 \times 62298.7$$

$$P_r = \frac{I^2 R_r}{2}$$

Execution:

N/run/I/run/A/run/λ/run/r/run/θ/run/H_{pk}/run/E_{pk}/run/P_{av}/run/R_r/run/P_r

MOTION OF ELECTRON IN TRANSVERSE MAGNETIC FIELD



Period, $T = \frac{2\pi m}{eB}$

Radius of path, $r = \frac{vT}{2\pi} \sin\theta$

Pitch of path, $P = vT\cos\theta$

Where θ = angle of injection

v = initial velocity

$= \sqrt{2\frac{e}{m}V}$,

V = equivalent voltage

Execution:

(a) V/run/θ/run/B/run/T/run/r/run/P

(b) goto/1/2/v/run/θ/run/B/run/T/run/r/run/P

KEY	#	KEY	#
HALT	00	rcl	40
√x	01	1	41
×	02	sin	42
5	03	=	43
./EE	04	stop	44
9	05	×	45
3	06	2	46
0	07	×	47
9	08	π	48
./EE	09	÷	49
5	10	rcl	50
=	11	1	51
sto	12	tan	52
0	13	=	53
stop	14	goto	54
sto	15	0	55
1	16	0	56
stop	17		57
1/x	18		58
×	19		59
3	20		60
./EE	21		61
5	22		62
7	23		63
2	24		64
4	25		65
./EE	26		66
1	27		67
1	28		68
+/−	29		69
=	30		70
stop	31		71
×	32		72
rcl	33		73
0	34		74
÷	35		75
2	36		76
÷	37		77
π	38		78
×	39		79

VELOCITY OF AN ACCELERATED ION

KEY	#	KEY	#
HALT	00		40
×	01		41
3	02		42
./EE	03		43
2	04		44
0	05		45
4	06		46
4	07		47
./EE	08		48
1	09		49
9	10		50
+/−	11		51
×	12		52
stop	13		53
÷	14		54
stop	15		55
=	16		56
$\sqrt{x}$	17		57
goto	18		58
0	19		59
0	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

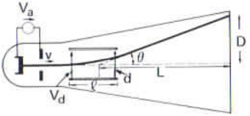
M = mass of ion
ne = charge on ion
V = accelerating potential (volts)

$$v = \sqrt{\frac{2neV}{M}}$$

Execution:

V/run/n/run/M/run/v

ELECTRO-STATIC DEFLECTION IN A CATHODE RAY



$$\theta = \arc \tan \frac{\ell V_d}{2dV_a}$$

$$D = \frac{\ell L V_d}{2dV_a}$$

$$S = \frac{\ell L}{2dV_a}$$

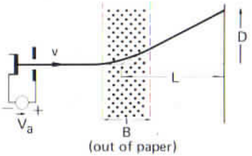
Execution:

V_a/run/ℓ/run/V_d/run/d/run/θ/
L/run/S/run/D

KEY	#	KEY	#
HALT	00		40
÷	01		41
stop	02		42
÷	03		43
stop	04		44
sto	05		45
1	06		46
×	07		47
stop	08		48
=	09		49
1/x	10		50
÷	11		51
2	12		52
=	13		53
sto	14		54
0	15		55
arc	16		56
tan	17		57
stop	18		58
×	19		59
rcl	20		60
0	21		61
÷	22		62
rcl	23		63
1	24		64
=	25		65
stop	26		66
×	27		67
rcl	28		68
1	29		69
=	30		70
goto	31		71
0	32		72
0	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

MAGNETIC DEFLECTION IN A CATHODE RAY TUBE

KEY	#	KEY	#
HALT	00	1	40
$\sqrt{x}$	01	goto	41
1/x	02	0	42
×	03	0	43
2	04		44
9	05		45
6	06		46
5	07		47
4	08		48
9	09		49
×	10		50
stop	11		51
=	12		52
sto	13		53
0	14		54
×	15		55
stop	16		56
=	17		57
arc	18		58
sin	19		59
sto	20		60
1	21		61
stop	22		62
+	23		63
(	24		64
×	25		65
rcl	26		66
1	27		67
tan	28		68
=	29		69
sto	30		70
1	31		71
0	32		72
)	33		73
×	34		74
rcl	35		75
0	36		76
=	37		77
stop	38		78
rcl	39		79



$$\theta = \arc\sin \frac{\ell B}{\sqrt{V_a}} \sqrt{\frac{e}{2m}}$$

$$D = L \tan\theta$$

$$S \simeq \frac{\ell L}{\sqrt{V_a}} \sqrt{\frac{e}{2m}}$$

Execution:

V_a/run/ℓ/run/B/run/θ/
L/run/S/run/D

WAVELENGTH IN A WAVEGUIDE

During signal transmission by waveguide, the wavelength within the waveguide is greater than the wavelength in an unbounded medium at the same frequency. The wavelength λ_g, in a rectangular waveguide is given by:

$$\lambda_g = \frac{\lambda}{\sqrt{1 - \left(\frac{n\lambda}{2a}\right)^2 - \left(\frac{m\lambda}{2b}\right)^2}}$$

for the n, m transmission mode, where λ is the wavelength in free space, and a,b are the waveguide dimensions.

This program computes the value of λ_g given the values of λ, a, b, n and m.

Execution:

λ/run/a/run/b/run/n/run/m/run/ λ_g

Example:

0.1/run/1/run/1/run/0/run/1/run/ 0.10012

KEY	#	KEY	#
HALT	00	÷	40
sto	01	rcl	41
0	02	1	42
stop	03	)	43
sto	04	x^2	44
1	05	=	45
stop	06	$\sqrt{x}$	46
sto	07	sto	47
2	08	5	48
stop	09	rcl	49
sto	10	0	50
3	11	÷	51
stop	12	rcl	52
sto	13	5	53
4	14	=	54
×	15	stop	55
rcl	16	goto	56
0	17	0	57
÷	18	1	58
2	19		59
÷	20		60
rcl	21		61
2	22		62
=	23		63
x^2	24		64
sto	25		65
6	26		66
1	27		67
−	28		68
rcl	29		69
6	30		70
−	31		71
(	32		72
rcl	33		73
3	34		74
×	35		75
rcl	36		76
0	37		77
÷	38		78
2	39		79

35. ELECTRICAL FOURIER ANALYSIS

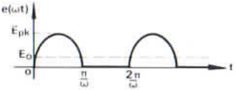
We express a periodic voltage as a Fourier series in the form

$$E(\omega t) = E_0 + \sum_{k=1}^{\infty} E_k \cos(k\omega t + \phi_k)$$

The following programs find the Fourier coefficients E_i and phase angles ϕ_i given the peak voltage E_{pk}.

35.1 Half wave rectification
35.2 Full wave rectification
35.3 Square wave
35.4 Triangular wave
35.5 Sawtooth wave
35.6 Rectangular pulse of duty cycle d
35.7 Assymetric triangular wave

HALF WAVE RECTI-FICATION



$$E_0 = \frac{1}{\pi} E_{pk}$$

$$E_1 = \frac{E_{pk}}{2} \quad \phi_1 = \frac{3\pi}{2}$$

$$E_{2n} = \frac{E_{pk}}{(4n^2 - 1)\pi} \quad \phi_{2n} = 0$$

$$E_{2n+1} = 0$$

Execution:

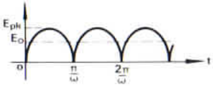
E_{pk}/run/n/run/E_{2n}/n/run/E_{2n} . . .

To enter new E_{pk}
goto/0/1/E_{pk}/run/ . . . etc

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
x^2	04		44
×	05		45
4	06		46
−	07		47
1	08		48
×	09		49
π	10		50
=	11		51
1/x	12		52
×	13		53
rcl	14		54
0	15		55
=	16		56
goto	17		57
0	18		58
3	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
x^2	04		44
×	05		45
4	06		46
—	07		47
1	08		48
×	09		49
π	10		50
=	11		51
1/x	12		52
×	13		53
rcl	14		54
0	15		55
×	16		56
2	17		57
=	18		58
goto	19		59
0	20		60
3	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

FULL WAVE RECTI- FICATION



$$E_0 = \frac{2}{\pi} E_{pk}$$

$$E_{2n-1} = 0$$

$$E_{2n} = \frac{2E_{pk}}{(4n^2 - 1)\pi}$$

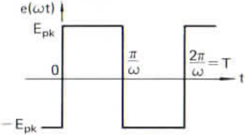
$$\phi_n = 0$$

Execution:

E_{pk}/run/n/run/E_{2n}/n/run/E_{2n} . . .

To enter new E_{pk}
goto/0/1/E_{pk}/run/ . . . etc

SQUARE WAVE



$$E_{2n} = 0$$

$$E_{2n+1} = \frac{4E_{pk}}{(2n+1)\pi}$$

$$\phi_n = \frac{3\pi}{2}$$

Execution:

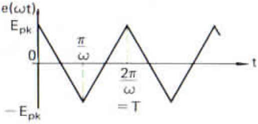
E_{pk}/run/n/run/E_{2n-1}/n/run/E_{2n-1} . . .

To enter new E_{pk}: goto/0/1/E_{pk}/run/ etc

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
×	04		44
2	05		45
—	06		46
1	07		47
×	08		48
π	09		49
=	10		50
1/x	11		51
×	12		52
rcl	13		53
0	14		54
×	15		55
4	16		56
=	17		57
goto	18		58
0	19		59
3	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

TRI-ANGULAR WAVE

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
×	04		44
2	05		45
—	06		46
1	07		47
×	08		48
π	09		49
=	10		50
x^2	11		51
1/x	12		52
×	13		53
rcl	14		54
0	15		55
×	16		56
8	17		57
=	18		58
goto	19		59
0	20		60
3	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



$$E_{2n-1} = \frac{8E_{pk}}{(2n-1)^2\pi^2}$$

$$E_{2n} = 0$$

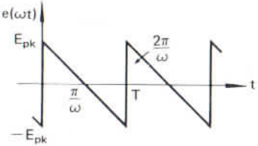
$$\phi_n = 0$$

Execution:

E_{pk}/run/n/run/E_{2n-1}/n/run/E_{2n-1} . . .

To enter new E_{pk}: goto/0/1/E_{pk}/run etc

SAWTOOTH WAVE



$E_0 = 0$

$\phi_n = \dfrac{3\pi}{2}$

$E_n = \dfrac{2}{n\pi} E_{pk}$

Execution:

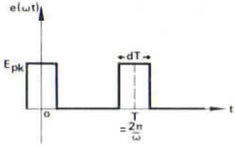
E_{pk}/run/n/run/E_n/n/run/E_n . . .

To enter new E_{pk}
goto/0/1/E_{pk}/run . . . etc

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
×	04		44
π	05		45
=	06		46
1/x	07		47
×	08		48
2	09		49
×	10		50
rcl	11		51
0	12		52
=	13		53
goto	14		54
0	15		55
3	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
stop	03		43
sto	04		44
1	05		45
stop	06		46
÷	07		47
(	08		48
×	09		49
1	10		50
8	11		51
0	12		52
×	13		53
rcl	14		54
1	15		55
=	16		56
sin	17		57
)	18		58
×	19		59
π	20		60
=	21		61
1/x	22		62
×	23		63
2	24		64
×	25		65
rcl	26		66
0	27		67
=	28		68
goto	29		69
0	30		70
6	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

RECTANGULAR PULSE TRAIN OF DUTY CYCLE D



$E_0 = dE_{pk}$

$\phi_n = 0$

$E_n = \dfrac{2}{n\pi} \sin n\pi d\, E_{pk}$

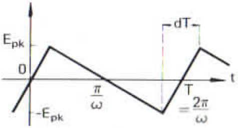
Execution:

E_{pk}/run/d/run/n/run/E_n/n/run/E_n . . .

To enter new E_{pk} and d goto/0/1/E_{pk}/run/d/run/etc

Error will occur if sin $n\pi d = 0$: clear /goto/0/7/n/run/. . . etc.

ASYM-METRICAL TRIANGULAR WAVE



$$E_0 = 0$$

$$E_n = \frac{2 \sin n\pi d}{n^2\pi^2 d(1-d)} E_{pk}$$

$$\phi_n = \frac{3\pi}{2}$$

Execution:

E_{pk}/run/d/run/n/run/E_n/n/run/E_n

To enter new E_{pk}, d
goto/0/1/E_{pk}/run/d/run/ . . . etc

KEY	#	KEY	#
HALT	00	=	40
sto	01	goto	41
0	02	0	42
stop	03	6	43
sto	04		44
1	05		45
stop	06		46
sto	07		47
2	08		48
×	09		49
1	10		50
8	11		51
0	12		52
×	13		53
rcl	14		54
1	15		55
=	16		56
sin	17		57
×	18		58
2	19		59
×	20		60
rcl	21		61
0	22		62
÷	23		63
rcl	24		64
2	25		65
x^2	26		66
÷	27		67
π	28		68
x^2	29		69
÷	30		70
rcl	31		71
1	32		72
÷	33		73
(	34		74
1	35		75
—	36		76
rcl	37		77
1	38		78
)	39		79

36. HEAT CONDUCTION SHAPE FACTORS

36.1 Cylinder
36.2 Sphere
36.3 Horizontal disc
36.4 Buried Sphere

In these programs F = shape factor

CYLINDER

r_1 = inside radius
r_0 = outside radius
L = length

$$F = \frac{2\pi L}{\ln \frac{r_0}{r_1}}$$

Execution:

r_0/run/r_1/run/L/run/F

KEY	#	KEY	#
HALT	00		40
÷	01		41
stop	02		42
=	03		43
ln	04		44
1/x	05		45
×	06		46
2	07		47
×	08		48
stop	09		49
×	10		50
π	11		51
=	12		52
goto	13		53
0	14		54
0	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

SPHERE

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
×	03		43
stop	04		44
sto	05		45
1	06		46
×	07		47
4	08		48
×	09		49
π	10		50
÷	11		51
(	12		52
rcl	13		53
0	14		54
−	15		55
rcl	16		56
1	17		57
)	18		58
=	19		59
goto	20		60
0	21		61
0	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

r_0 = outside radius

r_1 = inside radius

$$F = \frac{4\pi r_0 r_1}{r_0 - r_1}$$

Execution:

r_0/run/r_1/run/F

HORIZONTAL DISC

r = radius
D = centre line depth

$$F = \frac{2.22r}{1 - \frac{r}{2.83D}}$$

Execution:

r/run/D/run/F

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
×	03		43
2	04		44
./EE	05		45
2	06		46
2	07		47
÷	08		48
(	09		49
rcl	10		50
0	11		51
÷	12		52
2	13		53
./EE	14		54
8	15		55
3	16		56
÷	17		57
stop	18		58
−	19		59
1	20		60
)	21		61
+/−	22		62
=	23		63
goto	24		64
0	25		65
0	26		66
	27		77
	28		78
	29		79
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
÷	01		41
(	02		42
÷	03		43
stop	04		44
÷	05		45
2	06		46
—	07		47
1	08		48
)	09		49
×	10		50
π	11		51
+/−	12		52
=	13		53
goto	14		54
0	15		55
0	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

BURIED SPHERE

r = radius

D = centre line depth

$$F = \frac{\pi r}{1 - \frac{r}{2D}}$$

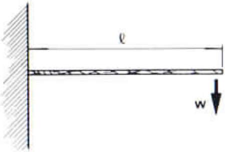
Execution:

r/run/D/run/F

37. BEAM BENDING

37.1 One fixed end, single load at free end
37.2 One fixed end, uniformly distributed load
37.3 Simply supported beam, one central load
37.4 Simply supported beam, uniformly distributed load
37.5 Fixed at both ends, one central load
37.6 Fixed at both ends, one acentric load
37.7 Fixed at both ends, uniformly distributed load
37.8 One fixed end, one pinned end, rotation at fixed end
37.9 One fixed end, one pinned end, rotation at pinned end
37.10 Fixed at both ends, ends displaced

ONE FIXED END, LOAD W AT FREE END



end slope $= \frac{W\ell^2}{2EI}$

end deflection

$= \frac{W\ell^3}{3EI}$

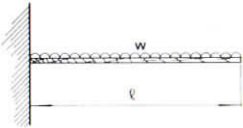
Execution:

ℓ/run/W/run/E/run/I/run/slope/run/deflection

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
x^2	03		43
×	04		44
stop	05		45
÷	06		46
2	07		47
÷	08		48
stop	09		49
÷	10		50
stop	11		51
=	12		52
stop	13		53
×	14		54
rcl	15		55
0	16		56
×	17		57
2	18		58
÷	19		59
3	20		60
=	21		61
goto	22		62
0	23		63
0	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
x^2	03		43
×	04		44
stop	05		45
÷	06		46
6	07		47
÷	08		48
stop	09		49
÷	10		50
stop	11		51
=	12		52
stop	13		53
×	14		54
rcl	15		55
0	16		56
×	17		57
./EE	18		58
7	19		59
5	20		60
=	21		61
goto	22		62
0	23		63
0	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

ONE FIXED END EQUALLY DISTRIB-UTED LOAD W



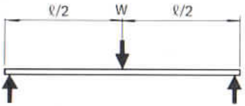
slope $= \frac{W\ell^2}{6EI}$

deflection $= \frac{W\ell^3}{8EI}$

Execution:

ℓ/run/W/run/E/run/I/run/slope/run/deflection

SIMPLY SUPPORTED WITH CENTRAL LOAD W



end slope $= \dfrac{W\ell^2}{16EI}$

central deflection

$$= \frac{W\ell^3}{48EI}$$

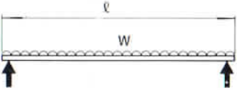
Execution:

ℓ/run/W/run/E/run/I/run/slope/
run/deflection

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
x^2	03		43
×	04		44
stop	05		45
÷	06		46
1	07		47
6	08		48
÷	09		49
stop	10		50
÷	11		51
stop	12		52
=	13		53
stop	14		54
×	15		55
rcl	16		56
0	17		57
÷	18		58
3	19		59
=	20		60
goto	21		61
0	22		62
0	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

SIMPLY SUPPORTED BEAM WITH DISTRIB-UTED LOAD

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
x^2	03		43
×	04		44
stop	05		45
÷	06		46
2	07		47
4	08		48
÷	09		49
stop	10		50
÷	11		51
stop	12		52
=	13		53
stop	14		54
×	15		55
rcl	16		56
0	17		57
÷	18		58
3	19		59
./EE	20		60
2	21		61
=	22		62
goto	23		63
0	24		64
0	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



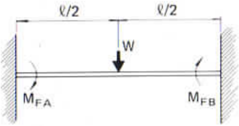
slope $= \dfrac{W\ell^2}{24EI}$

deflection $= \dfrac{5W\ell^3}{384EI}$

Execution:

ℓ/run/W/run/E/run/I/run/slope/run/deflection

BEAM WITH TWO FIXED ENDS AND CENTRAL LOADING W



$M_{FA} = -\frac{W\ell}{8}$

$M_{FB} = \frac{W\ell}{8}$

central deflection

$d = \frac{W\ell^3}{192EI}$

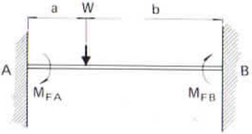
Execution:

W/run/ℓ/run/E/run/I/run/M_{FB}/run/d

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
sto	03		43
0	04		44
÷	05		45
8	06		46
=	07		47
sto	08		48
1	09		49
×	10		50
rcl	11		51
0	12		52
x^2	13		53
÷	14		54
stop	15		55
÷	16		56
stop	17		57
÷	18		58
2	19		59
4	20		60
=	21		61
sto	22		62
0	23		63
rcl	24		64
1	25		65
stop	26		66
rcl	27		67
0	28		68
goto	29		69
0	30		70
0	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

BEAM FIXED AT BOTH ENDS WITH LOAD W AT A DISTANCE a FROM END A

KEY	#	KEY	#
HALT	00	x^2	40
sto	01	=	41
0	02	goto	42
×	03	0	43
stop	04	0	44
sto	05		45
1	06		46
x^2	07		47
×	08		48
stop	09		49
sto	10		50
2	11		51
÷	12		52
(	13		53
rcl	14		54
0	15		55
+	16		56
rcl	17		57
1	18		58
)	19		59
x^2	20		60
=	21		61
stop	22		62
rcl	23		63
2	24		64
×	25		65
rcl	26		66
0	27		67
x^2	28		68
×	29		69
rcl	30		70
1	31		71
÷	32		72
(	33		73
rcl	34		74
0	35		75
+	36		76
rcl	37		77
1	38		78
)	39		79



$$M_{FA} = \frac{Wb^2a}{\ell^2}$$

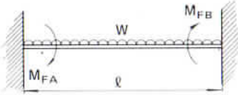
$$M_{FB} = \frac{Wa^2b}{\ell^2}$$

$$\ell = a + b$$

Execution:

a/run/b/run/W/
run/M_{FA}/run/M_{FB}

TWO FIXED ENDS AND EVENLY DISTRIBUTED LOAD



$$M_{FA} = -\frac{W\ell}{12}$$

$$M_{FB} = \frac{W\ell}{12}$$

$$d = \frac{W\ell^3}{384EI}$$

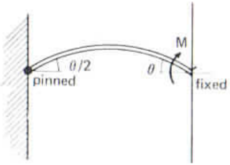
Execution:

W/run/ℓ/run/M_{FB}/E/run/I/run/d

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
sto	03		43
0	04		44
÷	05		45
1	06		46
2	07		47
÷	08		48
stop	09		49
÷	10		50
stop	11		51
×	12		52
rcl	13		53
0	14		54
x^2	15		55
÷	16		56
3	17		57
2	18		58
=	19		59
goto	20		60
0	21		61
0	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
÷	03		43
stop	04		44
÷	05		45
stop	06		46
÷	07		47
3	08		48
=	09		49
goto	10		50
0	11		51
0	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

ONE FIXED END, ONE PINNED END-EFFECT OF ROTATION AT FIXED END



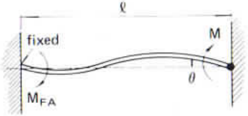
Applied moment = M

end slope = $\frac{M\ell}{3EI}$

Execution:

M/run/ℓ/run/E/run/I/run/slope

ONE FIXED END, ONE PINNED END-ROTATION AT PINNED END



Applied moment = M

slope = $\frac{M\ell}{4EI}$

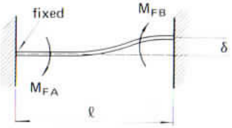
Execution:

M/run/ℓ/run/E/run/I/run/slope

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
÷	03		43
stop	04		44
÷	05		45
stop	06		46
÷	07		47
4	08		48
=	09		49
goto	10		50
0	11		51
0	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

END DISPLACEMENT AT BEAM FIXED AT BOTH ENDS

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
×	03		43
stop	04		44
×	05		45
stop	06		46
÷	07		47
stop	08		48
x^2	09		49
×	10		50
6	11		51
=	12		52
goto	13		53
0	14		54
0	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



Moments due to end displacement

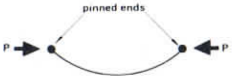
$$M_{FA} = M_{FB} = \frac{6EI\delta}{\ell^2}$$

Execution:

E/run/I/run/δ/run/ℓ/run/M_{FA}

38. STRUTS-CRITICAL LOAD

CRITICAL LOAD ON STRUT PINNED AT BOTH ENDS



$$P_{crit} = \frac{\pi^2 EI}{\ell^2}$$

Execution:

E/run/I/run/
ℓ/run/P_{crit}

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
×	03		43
π	04		44
x^2	05		45
÷	06		46
stop	07		47
x^2	08		48
=	09		49
goto	10		50
0	11		51
0	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

CRITICAL LOAD FOR STRUT FIXED AT ONE END, PINNED AT THE OTHER END

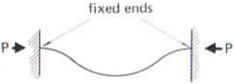
KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
×	03		43
π	04		44
x^2	05		45
×	06		46
2	07		47
÷	08		48
stop	09		49
x^2	10		50
=	11		51
goto	12		52
0	13		53
0	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

$$P_{crit} = \frac{2\pi^2 EI}{\ell^2}$$

Execution:

E/run/I/run/
ℓ/run/ P_{crit}

STRUT WITH TWO FIXED ENDS



$$P_{crit} = \frac{4\pi^2 EI}{\ell^2}$$

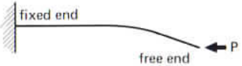
Execution:

E/run/I/run/ℓ/run/P_{crit}

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
×	03		43
π	04		44
x^2	05		45
×	06		46
4	07		47
÷	08		48
stop	09		49
x^2	10		50
=	11		51
goto	12		52
0	13		53
0	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
×	03		43
π	04		44
x^2	05		45
÷	06		46
4	07		47
÷	08		48
stop	09		49
x^2	10		50
=	11		51
goto	12		52
0	13		53
0	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

STRUT WITH ONE FIXED AND ONE FREE END



$$P_{crit} = \frac{\pi^2 EI}{4\ell^2}$$

Execution:

E/run/I/run/
ℓ/run/ P_{crit}

39. STRESS AND STRAIN

TORSION OF THIN WALLED TUBE

$$\text{Torque} = 2\pi r^3 tG \frac{\theta}{L}$$

$$\frac{\theta}{L} = \text{twist per unit length}$$

$$= \frac{\text{angular deflection}}{\text{length}}$$

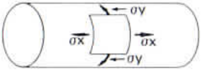
Execution:

r/run/t/run/G/run/$\frac{\theta}{L}$/run/torque

KEY	#	KEY	#
HALT	00		40
×	01		41
(	02		42
x^2	03		43
)	04		44
×	05		45
2	06		46
×	07		47
π	08		48
×	09		49
stop	10		50
×	11		51
stop	12		52
×	13		53
stop	14		54
=	15		55
goto	16		56
0	17		57
0	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
÷	03		43
stop	04		44
÷	05		45
4	06		46
=	07		47
stop	08		48
×	09		49
2	10		50
=	11		51
goto	12		52
0	13		53
0	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

CYLINDRICAL PRESSURE VESSEL



Longitudinal stress,

$$\sigma_x = \frac{pd}{4t}$$

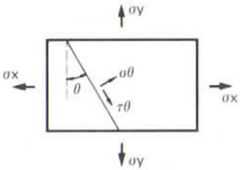
Hoop stress,

$$\sigma_y = \frac{pd}{2t}$$

Execution:

p/run/d/run/t/run/σ_x /run/σ_y

COMPLEX STRESSES



$$\sigma_\theta = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta$$

$$\tau_\theta = \frac{\sigma_x - \sigma_y}{2} \sin 2\theta$$

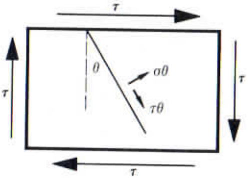
Execution:

θ/run/σ_x/run/σ_y/run/σ_θ/run/τ_θ

KEY	#	KEY	#
HALT	00	0	40
×	01	sin	41
2	02	=	42
=	03	goto	43
sto	04	0	44
0	05	0	45
stop	06		46
sto	07		47
1	08		48
stop	09		49
sto	10		50
2	11		51
+	12		52
rcl	13		53
1	14		54
÷	15		55
2	16		56
+	17		57
(	18		58
rcl	19		59
1	20		60
−	21		61
rcl	22		62
2	23		63
÷	24		64
2	25		65
=	26		66
sto	27		67
2	28		68
×	29		69
rcl	30		70
0	31		71
cos	32		72
)	33		73
=	34		74
stop	35		75
rcl	36		76
2	37		77
×	38		78
rcl	39		79

COMPLEX STRESSES

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
×	03		43
(	04		44
stop	05		45
×	06		46
2	07		47
=	08		48
sto	09		49
1	10		50
sin	11		51
)	12		52
=	13		53
stop	14		54
rcl	15		55
1	16		56
cos	17		57
×	18		58
rcl	19		59
0	20		60
+/−	21		61
=	22		62
goto	23		63
0	24		64
0	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



$\sigma_\theta = \tau \sin 2\theta$

$\tau_\theta = -\tau \cos 2\theta$

Execution:

τ/run/θ/run/σ_θ/run/τ_θ

ELASTIC STRAIN ENERGY

In tension,

$$S_t = \frac{\sigma^2}{2E}$$

In torsion,

$$S_\tau = \frac{\tau^2}{2G}$$

Execution:

(a) σ/run/E/run/S_t
(b) τ/run/G/run/S_τ

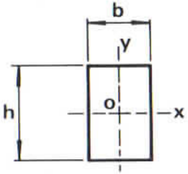
KEY	#	KEY	#
HALT	00		40
x^2	01		41
÷	02		42
2	03		43
÷	04		44
stop	05		45
=	06		46
goto	07		47
0	08		48
0	09		49
	10		50
	11		51
	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

40. ELASTIC AND PLASTIC SECTION MODULI

In this section:

Z_e = elastic section modulus
Z_p = plastic section modulus
$S = \dfrac{Z_p}{Z_e}$ = shape factor

SOLID RECT-ANGULAR SECTION



$$Z_e^y = \frac{b^2h}{6}$$

$$Z_p^y = \frac{b^2h}{4}$$

$$S = 1.5$$

$$Z_e^z = \frac{bh^2}{6}$$

$$Z_p^z = \frac{bh^2}{4}$$

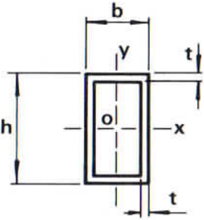
Execution:

b/run/h/run/Z_e for C_y/run/ Z_p for C_y/run/Z_e for C_z/run/ Z_p for C_z

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
x^2	03		43
×	04		44
stop	05		45
sto	06		46
1	07		47
÷	08		48
6	09		49
=	10		50
stop	11		51
×	12		52
1	13		53
./EE	14		54
5	15		55
=	16		56
stop	17		57
rcl	18		58
0	19		59
×	20		60
rcl	21		61
1	22		62
x^2	23		63
÷	24		64
6	25		65
=	26		66
stop	27		67
×	28		68
1	29		69
./EE	30		70
5	31		71
=	32		72
goto	33		73
0	34		74
0	35		75
	36		76
	37		77
	38		78
	39		79

THIN WALLED RECT-ANGULAR BOX

KEY	#	KEY	#
HALT	00	rcl	40
sto	01	0	41
0	02	=	42
stop	03	goto	43
sto	04	0	44
1	05	0	45
stop	06		46
sto	07		47
2	08		48
×	09		49
(	10		50
rcl	11		51
1	12		52
÷	13		53
3	14		54
+	15		55
rcl	16		56
0	17		57
)	18		58
×	19		59
rcl	20		60
1	21		61
=	22		62
sto	23		63
0	24		64
stop	25		65
+	26		66
(	27		67
rcl	28		68
1	29		69
x^2	30		70
×	31		71
rcl	32		62
2	33		73
÷	34		74
6	35		75
)	36		76
=	37		77
stop	38		78
÷	39		79



Axis C_y:

$$Z_e = bt\left(h + \frac{b}{3}\right)$$

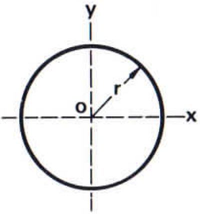
$$Z_p = bt\left(h + \frac{b}{2}\right)$$

$$S = \frac{h + \frac{b}{2}}{h + \frac{b}{3}}$$

Execution:

h/run/b/run/t/run/Z_e/run/Z_p/run/S

SOLID CIRCULAR SECTION



$$Z_e = \frac{\pi r^3}{4}$$

$$Z_p = \frac{4r^3}{3}$$

$$S = \frac{16}{3\pi} = 1.697953$$

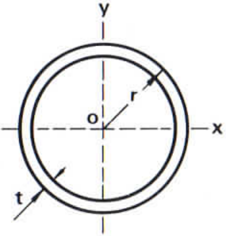
Execution:

r/run/Z_e/run/Z_p

KEY	#	KEY	#
HALT	00		40
×	01		41
(	02		42
x^2	03		43
)	04		44
÷	05		45
4	06		46
×	07		47
π	08		48
=	09		49
stop	10		50
×	11		51
1	12		52
6	13		53
÷	14		54
3	15		55
÷	16		56
π	17		57
=	18		58
goto	19		59
0	20		60
0	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

THIN WALLED CIRCULAR TUBE

KEY	#	KEY	#
HALT	00		40
x^2	01		41
×	02		42
stop	03		43
×	04		44
π	05		45
=	06		46
stop	07		47
×	08		48
4	09		49
÷	10		50
π	11		51
=	12		52
goto	13		53
0	14		54
0	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



$Z_e = \pi r^2 t$

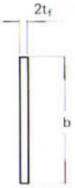
$Z_p = 4r^2 t$

$S = \frac{4}{\pi} = 1.273240$

Execution:

r/run/t/run/Z_e/run Z_p

THIN I SECTION



Axis C_y:

$$Z_e = \frac{b^2 t_f}{3}$$

$$Z_p = \frac{b^2 t_f}{2}$$

$$S = 1.5$$

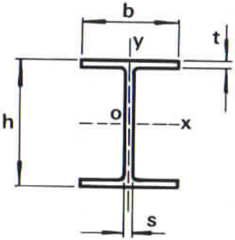
Execution:

b/run/t_f/run/Z_e/run/Z_p

KEY	#	KEY	#
HALT	00		40
x^2	01		41
×	02		42
stop	03		43
÷	04		44
3	05		45
=	06		46
stop	07		47
×	08		48
1	09		49
./EE	10		50
5	11		51
=	12		52
goto	13		53
0	14		54
0	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

Z_e AND Z_p FOR THIN I SECTION

KEY	#	KEY	#
HALT	00	goto	40
sto	01	0	41
0	02	0	42
×	03		43
stop	04		44
=	05		45
sto	06		46
1	07		47
÷	08		48
6	09		49
+	10		50
(	11		51
stop	12		52
×	13		53
stop	14		54
)	15		55
×	16		56
rcl	17		57
0	18		58
=	19		59
stop	20		60
sto	21		61
2	22		62
+	23		63
(	24		64
rcl	25		65
0	26		66
×	27		67
rcl	28		68
1	29		69
÷	30		70
1	31		71
2	32		72
)	33		73
=	34		74
stop	35		75
÷	36		76
rcl	37		77
2	38		78
=	39		79



Axis C_y:

$$Z_e = h\left(bt + \frac{hs}{6}\right)$$

$$Z_p = h\left(bt + \frac{hs}{4}\right)$$

$$S = \frac{bt + \frac{hs}{4}}{bt + \frac{hs}{6}}$$

Execution:

h/run/s/run/b/run/t/run/ Z_e/run/ Z_p/run/ S

41. ELECTRONIC CIRCUIT DESIGN

41.1 Wavelength/frequency conversion
41.2 Reactance/frequency conversion
41.3 Decibel conversion
41.4 Magnitude and phase of an impedance
41.5 Resistors in parallel
41.6 Voltage drop across resistive voltage divider
41.7 Resistance required to attain a given voltage drop
41.8 Resistance required to attain a given attenuation
41.9 Resistive L-pad
41.10 Impedance of a series circuit
41.11 Parallel to series conversion, R–X circuit
41.12 Parallel to series conversion, Z–X circuit
41.13 Parallel to series conversion, Z–Z circuit, (i)

WAVE LENGTH / FREQUENCY CONVERSION

$\nu\lambda = c$

Execution:

(a) Wavelength in metres/run/
frequency in Hertz

(b) Frequency in Hertz/run/
wavelength in metres

KEY	#	KEY	#
HALT	00		40
1/x	01		41
×	02		42
2	03		43
./EE	04		44
9	05		45
9	06		46
7	07		47
9	08		48
2	09		49
5	10		50
./EE	11		51
8	12		52
=	13		53
goto	14		54
0	15		55
0	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

REACTANCE/FREQUENCY CONVERSIONS

KEY	#	KEY	#
HALT	00		40
×	01		41
stop	02		42
×	03		43
2	04		44
×	05		45
π	06		46
=	07		47
goto	08		48
0	09		49
0	10		50
stop	11		51
×	12		52
stop	13		53
×	14		54
2	15		55
×	16		56
π	17		57
=	18		58
1/x	19		59
goto	20		60
1	21		61
1	22		62
stop	23		63
÷	24		64
stop	25		65
÷	26		66
2	27		67
÷	28		68
π	29		69
=	30		70
goto	31		71
2	32		72
3	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

$$X_C = \frac{1}{2\pi\nu C}$$

$$X_L = 2\pi\nu L$$

Execution:

(a) goto/0/1/L/run/ν/run/X_L

(b) goto/1/2/C/run/ν/run/X_C

(c) goto/1/2/X_C/run/ν/run/C

(d) goto/1/2/C/run/X_C/run/ν

(e) goto/2/4/X_L/run/ν/run/L

(f) goto/2/4/X_L/run/L/run/ν

DECIBEL CONVERSION

Power:

P_1 = observed level

P_0 = reference level

$$P_{dB} = 10 \log_{10} \frac{P_1}{P_0}$$

Intensity:

I_1 = observed level

I_0 = reference level

$$I_{dB} = 20 \log_{10} \frac{I_1}{I_0}$$

Store reference level for power in memory 0 and for intensity in memory 1.

Execution:

(a) goto/0/1/P_1/run/P_{dB}

(b) goto/1/4/P_{dB}/run/P_1

(c) goto/2/7/I_1/run/I_{dB}

(d) goto/4/0/I_{dB}/run/I_1

It is not necessary to repeat the /goto/ to repeat (a), (b), (c) or (d).

KEY	#	KEY	#
HALT	00	÷	40
÷	01	2	41
rcl	02	0	42
0	03	=	43
=	04	alog	44
log	05	×	45
×	06	rcl	46
1	07	1	47
0	08	=	48
=	09	stop	49
stop	10	goto	50
goto	11	4	51
0	12	0	52
1	13		53
÷	14		54
1	15		55
0	16		56
=	17		57
alog	18		58
×	19		59
rcl	20		60
0	21		61
=	22		62
stop	23		63
goto	24		64
1	25		65
4	26		66
÷	27		67
rcl	28		68
1	29		69
=	30		70
log	31		71
×	32		72
2	33		73
0	34		74
=	35		75
stop	36		76
goto	37		77
2	38		78
7	39		79

KEY	#	KEY	#
HALT	00		40
sto	01		41
0	02		42
x^2	03		43
+	04		44
stop	05		45
sto	06		46
1	07		47
x^2	08		48
=	09		49
$\sqrt{x}$	10		50
stop	11		51
rcl	12		52
0	13		53
÷	14		54
rcl	15		55
1	16		56
=	17		57
arc	18		58
tan	19		59
goto	20		60
0	21		61
0	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

MAGNITUDE AND PHASE OF IMPEDANCE

$$Z = R + jX$$

$$= |Z| e^{j\phi}$$

$$|Z| = \sqrt{R^2 + X^2}$$

$$\phi = \text{arc tan}\left(\frac{X}{R}\right)$$

Answer in degrees.

Execution:

X/run/R/run/|Z|/run/ϕ

RESISTORS IN PARALLEL

Pre-execution:

C/sto/0

Execution:

R_1 /run/ R_2 /run/ $\frac{R_1 R_2}{R_1 + R_2}$ /run/ R_3

/. . . / R_n /run/ R_{par}

To find resistor R_2 such that parallel combination of

R_1 and R_2 = R:

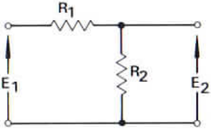
R/run/ R_1 /+/–/run/ R_2

This program can also be used for capacitors in series, inductors in parallel and conductors in series.

KEY	#	KEY	#
HALT	00		40
1/x	01		41
M +	02		42
0	03		43
rcl	04		44
0	05		45
1/x	06		46
goto	07		47
0	08		48
0	09		49
	10		50
	11		51
	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

RESISTIVE VOLTAGE DIVIDER

KEY	#	KEY	#
HALT	00		40
1/x	01		41
×	02		42
stop	03		43
×	04		44
stop	05		45
=	06		46
goto	07		47
0	08		48
0	09		49
	10		50
	11		51
	12		52
	13		53
	14		54
	15		55
	16		56
	17		57
	18		58
	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

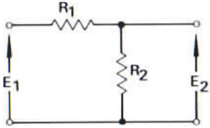


$R = R_1 + R_2$

Execution:

R/run/R_2/run/E_1/run/E_2

RESISTIVE VOLTAGE DIVIDER



$R = R_1 + R_2$

Execution:

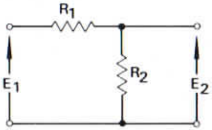
R/run/E_1/run/E_2/run/R_1/run/R_2

KEY	#	KEY	L
HALT	00		40
—	01		41
(	02		42
×	03		43
(	04		44
stop	05		45
1/x	06		46
×	07		47
stop	08		48
)	09		49
=	10		50
sto	11		51
0	12		52
)	13		53
=	14		54
stop	15		55
rcl	16		56
0	17		57
goto	18		58
0	19		59
0	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

RESISTIVE VOLTAGE DIVIDER

(also autotransformer of negligible resistance)

KEY	#	KEY	#
HALT	00		40
—	01		41
(	02		42
×	03		43
(	04		44
stop	05		45
÷	06		46
2	07		47
0	08		48
)	09		49
alog	10		50
=	11		51
sto	12		52
0	13		53
)	14		54
=	15		55
stop	16		56
rcl	17		57
0	18		58
goto	19		59
0	20		60
0	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



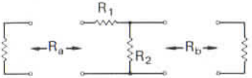
$$R = R_1 + R_2$$

$$A = 20 \log \frac{E_2}{E_1}$$

Execution:

R/run/A/run/R_1 /run/R_2

RESISTIVE L-PAD-MATCHING IMPEDANCES



$$R_1 = \sqrt{R_a(R_a - R_b)}$$

$$R_2 = \frac{R_a R_b}{R_1}$$

$$A_v = 20 \log \frac{R_a - R_1}{R_a}$$

$$A_i = 20 \log \frac{R_a}{R_a + R_1}$$

$$G = 10 \log \frac{R_a - R_1}{R_a + R_1}$$

Execution:

R_a/run/R_b/run/R_1/run/R_2/run/A_v/run/A_i/run/G

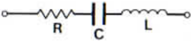
Restriction: $R_a > R_b$

KEY	#	KEY	#
HALT	00	stop	40
sto	01	rcl	41
0	02	0	42
−	03	÷	43
stop	04	(	44
×	05	+	45
rcl	06	rcl	46
0	07	1	47
=	08	)	48
$\sqrt{x}$	09	=	49
sto	10	log	50
1	11	×	51
stop	12	2	52
1/x	13	0	53
×	14	=	54
(	15	stop	55
rcl	16	rcl	56
0	17	0	57
x^2	18	−	58
−	19	rcl	59
rcl	20	1	60
1	21	÷	61
x^2	22	(	62
)	23	rcl	63
=	24	0	64
stop	25	+	65
rcl	26	rcl	66
0	27	1	67
−	28	)	68
rcl	29	=	69
1	30	log	70
÷	31	×	71
rcl	32	1	72
0	33	0	73
=	34	=	74
log	35	goto	75
×	36	0	76
2	37	0	77
0	38		78
=	39		79

KEY	#	KEY	#
HALT	00		40
sto	01		41
1	02		42
stop	03		43
sto	04		44
2	05		45
stop	06		46
×	07		47
2	08		48
×	09		49
π	10		50
=	11		51
sto	12		52
0	13		53
×	14		54
rcl	15		55
1	16		56
=	17		57
1/x	18		58
sto	19		59
3	20		60
rcl	21		61
0	22		62
×	23		63
rcl	24		64
2	25		65
−	26		66
rcl	27		67
3	28		68
=	29		69
stop	30		70
goto	31		71
0	32		72
1	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

IMPEDANCE OF A SERIES CIRCUIT

The impedance of a circuit consisting of a resistor, a capacitor and an inductor is series thus



is given at any frequency, f, by

$Z = R + jX$

where

$X = \omega L - \frac{1}{\omega C}$

and

$\omega = 2\pi f$

This program computes the value of the reactance, X, given the values of f, L and C.

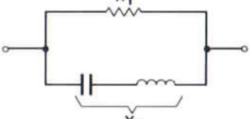
Execution:

C/run/L/run/f/run/X

Example:

10^{-3}/run/10^{-3}/run/1000/run
/6.1240305

CONVERSION OF A PARALLEL CIRCUIT TO AN EQUIVALENT SERIES CIRCUIT



The impedance of the parallel circuit is given by

$$Z = \frac{R_1 X_1^2 + jX_1 R_1^2}{X_1^2 + R_1^2}$$

Therefore, the equivalent series circuit has resistance,

$$R = \frac{R_1 X_1^2}{X_1^2 + R_1^2}$$

and reactance,

$$X = \frac{X_1 R_1^2}{X_1^2 + R_1^2}$$

This program computes the values of R and X given the values of R_1 and X_1.

Execution:

X_1/run/R_1/run/R/run/X

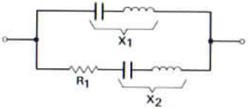
Example:

3/run/4/run/1.44/run/1.92

KEY	#	KEY	#
HALT	00	1	40
sto	01		41
0	02		42
stop	03		43
sto	04		44
1	05		45
x^2	06		46
+	07		47
(	08		48
rcl	09		49
0	10		50
)	11		51
x^2	12		52
=	13		53
sto	14		54
2	15		55
rcl	16		56
0	17		57
x^2	18		58
×	19		59
rcl	20		60
1	21		61
÷	22		62
rcl	23		63
2	24		64
=	25		65
stop	26		66
rcl	27		67
1	28		68
x^2	29		69
×	30		70
rcl	31		71
0	32		72
÷	33		73
rcl	34		74
2	35		75
=	36		76
stop	37		77
goto	38		78
0	39		79

KEY	#	KEY	#
HALT	00	×	40
sto	01	rcl	41
0	02	2	42
stop	03	+	43
sto	04	(	44
1	05	rcl	45
stop	06	0	46
sto	07	)	47
2	08	x^2	48
+	09	=	49
rcl	10	×	50
1	11	rcl	51
=	12	1	52
x^2	13	÷	53
+	14	rcl	54
(	15	3	55
rcl	16	=	56
0	17	stop	57
)	18	goto	58
x^2	19	0	59
=	20	1	60
sto	21		61
3	22		62
rcl	23		63
1	24		64
x^2	25		65
×	26		66
0	27		67
rcl	28		68
0	29		69
÷	30		70
rcl	31		71
3	32		72
=	33		73
stop	34		74
rcl	35		75
1	36		76
+	37		77
rcl	38		78
2	39		79

CONVERSION OF A PARALLEL CIRCUIT TO AN EQUIVALENT SERIES CIRCUIT



The impedance of the parallel circuit is given by

$$Z=\frac{R_1X_1^2+jX_1(R_1^2+X_2(X_1+X_2))}{(X_1+X_2)^2+R_1^2}$$

Therefore, the equivalent series circuit has resistance

$$R=\frac{R_1X_1^2}{(X_1+X_2)^2+R_1^2}$$

and reactance

$$X=\frac{X_1(R_1^2+X_2(X_1+X_2))}{(X_1+X_2)^2+R_1^2}$$

This program computes the values of R and X given the values of R_1, X_1 and X_2

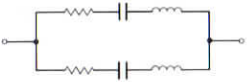
Execution:

R_1/run/X_1/run/X_2/run/R/run/X

Example:

5/run/3/run/2/run/0.9/run/2.1

CONVERSION OF A PARALLEL CIRCUIT TO AN EQUIVALENT SERIES CIRCUIT



The impedance of the parallel circuit is given by

$Z = R + jX$

where

$$R = \{(X_1 + X_2)(X_1R_2 + R_1X_2) + (R_1 + R_2)(R_1R_2 - X_1X_2)\}/D$$

$$X = \{(R_1 + R_2)(X_1R_2 + R_1X_2) - (X_1 + X_2)(R_1R_2 - X_1X_2)\}/D$$

where $D = (R_1 + R_2)^2 + (X_1 + X_2)^2$

Therefore, the equivalent series circuit has resistance R and reactance X. This program computes the value of R given the values of R_1, R_2, X_1 and X_2. The next program computes the value of X.

Execution:

R_1/run/R_2/run/X_1/run/X_2/run/R

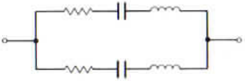
Example:

1/run/3/run/2/run/1/run/1

KEY	#	KEY	#
HALT	00	sto	40
sto	01	5	41
0	02	rcl	42
stop	03	1	43
sto	04	M +	44
1	05	0	45
stop	06	rcl	46
sto	07	3	47
2	08	M +	48
stop	09	2	49
sto	10	rcl	50
3	11	0	51
×	12	x^2	52
rcl	13	+	53
0	14	(	54
+	15	rcl	55
(	16	2	56
rcl	17	)	57
2	18	x^2	58
×	19	=	59
rcl	20	sto	60
1	21	6	61
)	22	rcl	62
=	23	2	63
sto	24	×	64
4	25	rcl	65
rcl	26	4	66
0	27	+	67
×	28	(	68
rcl	29	rcl	69
1	30	0	70
—	31	×	71
(	32	rcl	72
rcl	33	5	73
2	34	)	74
×	35	÷	75
rcl	36	0	76
3	37	rcl	77
)	38	6	78
=	39	=	79

KEY	#	KEY	#
HALT	00	sto	40
sto	01	5	41
0	02	rcl	42
stop	03	1	43
sto	04	M +	44
1	05	0	45
stop	06	rcl	46
sto	07	3	47
2	08	M +	48
stop	09	2	49
sto	10	rcl	50
3	11	0	51
×	12	x^2	52
rcl	13	+	53
0	14	(	54
+	15	rcl	55
(	16	2	56
rcl	17	)	57
2	18	x^2	58
×	19	=	59
rcl	20	sto	60
1	21	6	61
)	22	rcl	62
=	23	0	63
sto	24	×	64
4	25	rcl	65
rcl	26	4	66
0	27	—	67
×	28	(	68
rcl	29	rcl	69
1	30	2	70
—	31	×	71
(	32	rcl	72
rcl	33	5	73
2	34	)	74
×	35	÷	75
rcl	36	0	76
3	37	rcl	77
)	38	6	78
=	39	=	79

CONVERSION OF A PARALLEL CIRCUIT TO AN EQUIVALENT SERIES CIRCUIT



This program computes the reactance, X, of the series circuit equivalent to the parallel circuit described for the previous program.

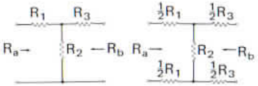
Execution:

R_1/run/R_2/run/X_1/run/X_2/run/X

Example:

1/run/3/run/2/run/2/run/1.125

RESISTIVE ATTEN-UATOR SECTIONS T-TYPE



$$R_0 = \sqrt{R_a R_b}$$

$$\rho = \frac{R_a}{R_0} = \frac{R_0}{R_b}$$

Design attenuation, a,

$$= \sqrt{a_v a_i}$$

Power attenuation, A,

$$= -20 \log a.$$

Forward voltage transfer ratio

$$= a_v = \frac{a}{\rho}.$$

Forward current transfer ratio

$$= a_i = a\rho.$$

Restriction: $a < 1$.

$$R_1 = \frac{\rho(1+a^2) - 2a}{1-a^2} R_0$$

$$R_2 = \frac{2a}{1-a^2} R_0$$

$$R_3 = \frac{1}{\rho}\frac{(1+a^2) - 2a}{1-a^2} R_0$$

KEY	#	KEY	#
HALT	00	=	40
+/−	01	sto	41
÷	02	3	42
2	03	)	43
0	04	−	44
=	05	(	45
alog	06	rcl	46
stop	07	0	47
sto	08	×	48
0	09	2	49
stop	10	÷	50
÷	11	(	51
(	12	1	52
×	13	−	53
stop	14	rcl	54
=	15	0	55
$\sqrt{x}$	16	x^2	56
sto	17	)	57
1	18	×	58
)	19	rcl	59
=	20	1	60
stop	21	=	61
sto	22	sto	62
2	23	0	63
×	24	)	64
(	25	=	65
rcl	26	stop	66
0	27	rcl	67
x^2	28	0	68
+	29	stop	69
1	30	rcl	70
÷	31	3	71
(	32	÷	72
+/−	33	rcl	73
+	34	2	74
2	35	−	75
)	36	0	76
×	37	rcl	77
rcl	38	0	78
1	39	=	79

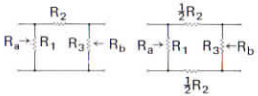
Execution:

(a) A/run/a/run/R_a/run/R_b/run/ρ
/run/R_1/run/R_2/run/R_3

or

(b) goto/0/8/a/run/R_a/run/R_b
/run/ρ/run/R_1/run/R_2/run/R_3

RESISTANCE ATTENUATOR SECTION, π TYPE



$R_0 = \sqrt{R_a R_b}$

$\rho = \frac{R_a}{R_0} = \frac{R_0}{R_b}$

a_v = forward current transfer ratio

$= \frac{a}{\rho}$

a_i = forward current transfer ratio

$= a\rho$

a = design attenuation

$= \sqrt{a_v a_i}$

A = power attenuation

$= -20 \log a$

$$R_1 = \frac{1 - a^2}{\frac{1}{\rho}(1 + a^2) - 2a} R_0$$

$$R_3 = \frac{1 - a^2}{\rho(1 + a^2) - 2a} R_0$$

$$R_2 = \frac{1 - a^2}{2a}$$

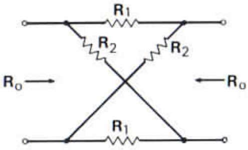
KEY	#	KEY	#
HALT	00	sto	40
+/−	01	4	41
÷	02	+/−	42
2	03	+	43
0	04	(	44
=	05	rcl	45
alog	06	3	46
stop	07	÷	47
sto	08	rcl	48
0	09	2	49
stop	10	)	50
÷	11	÷	51
(	12	rcl	52
×	13	1	53
stop	14	=	54
=	15	1/x	55
√x	16	stop	56
sto	17	rcl	57
1	18	1	58
)	19	÷	59
=	20	rcl	60
sto	21	4	61
2	22	=	62
stop	23	stop	63
rcl	24	rcl	64
0	25	3	65
arc	26	×	66
tan	27	rcl	67
×	28	2	68
2	29	−	69
=	30	rcl	70
sto	31	4	71
0	32	÷	72
cos	33	rcl	73
1/x	34	1	74
sto	35	=	75
3	36	1/x	76
rcl	37	goto	77
0	38	0	78
tan	39	0	79

Execution:

(a) A/run/a/run/R_a/run/R_b/run/ρ /run/R_1/run/R_2/run/R_3

(b) goto/0/8/a/run/R_a/run/R_b /run/ρ/run/R_1/run/R_2/run /R_3

LATTICE ATTENUATOR SECTIONS



$a_v = a_i = a$

$A = -20 \log a$

Characteristic impedance $= R_o$

$$R_1 = \frac{1-a}{1+a} R_o$$

$$R_2 = \frac{1+a}{1-a} R_o$$

Execution:

(a) A/run/a/run/R_o/run/R_1/run/R_2

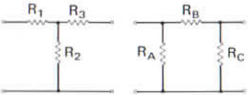
or

(b) goto/0/8/a/run/R_o/run/R_1/run/R_2

KEY	#	KEY	#
HALT	00		40
÷	01		41
2	02		42
0	03		43
+/−	04		44
=	05		45
alog	06		46
stop	07		47
sto	08		48
0	09		49
stop	10		50
sto	11		51
1	12		52
×	13		53
(	14		54
rcl	15		55
0	16		56
+/−	17		57
+	18		58
1	19		59
÷	20		60
(	21		61
+/−	22		62
+	23		63
2	24		64
)	25		65
)	26		66
=	27		67
stop	28		68
1/x	29		69
×	30		70
rcl	31		71
1	32		72
x^2	33		73
=	34		74
goto	35		75
0	36		76
0	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00	rcl	40
sto	01	0	41
0	02	=	42
×	03	goto	43
stop	04	0	44
sto	05	0	45
1	06		46
×	07		47
stop	08		48
sto	09		49
2	10		50
÷	11		51
(	12		52
rcl	13		53
0	14		54
+	15		55
rcl	16		56
1	17		57
+	18		58
rcl	19		59
2	20		60
)	21		61
=	22		62
sto	23		63
3	24		64
÷	25		65
rcl	26		66
2	27		67
=	28		68
stop	29		69
rcl	30		70
3	31		71
÷	32		72
rcl	33		73
1	34		74
=	35		75
stop	36		76
rcl	37		77
3	38		78
÷	39		79

RESISTIVE NETWORKS T TO Π TRANS-FORMATION



$$R_0^2 = \frac{R_A R_B R_C}{R_A + R_B + R_C}$$

$$= R_1 R_2 + R_2 R_3 + R_3 R_1$$

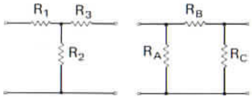
$$R_1 R_C = R_2 R_B = R_3 R_A = R_0^2$$

Execution:

R_A/run/R_B/run/R_C/run/R_1/run/R_2/run/R_3

to find R_0: rcl/3/$\sqrt{x}$/

RESISTIVE NETWORKS π TO T TRANSFORMATION



Execution:

R_1/run/R_2/run/R_3/run/R_A/run/R_B/run/R_C

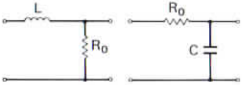
to find R_0: rcl/0/$\sqrt{x}$/

KEY	#	KEY	#
HALT	00	1	40
sto	01	=	41
1	02	stop	42
×	03	goto	43
(	04	0	44
stop	05	1	45
sto	06		46
2	07		47
+	08		48
stop	09		49
sto	10		50
3	11		51
)	12		52
+	13		53
(	14		54
rcl	15		55
2	16		56
×	17		57
rcl	18		58
3	19		59
)	20		60
=	21		61
sto	22		62
0	23		63
÷	24		64
rcl	25		65
3	26		66
=	27		67
stop	28		68
rcl	29		69
0	30		70
÷	31		71
rcl	32		72
2	33		73
=	34		74
stop	35		75
rcl	36		76
0	37		77
÷	38		78
rcl	39		79

SIMPLE FILTERS

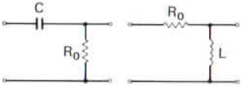
KEY	#	KEY	#
HALT	00	−	40
÷	01	1/x	41
rcl	02	=	42
0	03	1/x	43
=	04	÷	44
goto	05	rcl	45
5	06	0	46
6	07	×	47
1/x	08	(	48
×	09	rcl	49
rcl	10	1	50
0	11	−	51
+/−	12	rcl	52
=	13	2	53
goto	14	)	54
5	15	=	55
6	16	sto	56
÷	17	3	57
rcl	18	x^2	58
0	19	+	59
−	20	1	60
1/x	21	=	61
×	22	$\sqrt{x}$	62
rcl	23	log	63
0	24	×	64
÷	25	2	65
(	26	0	66
rcl	27	+/−	67
2	28	=	68
−	29	stop	69
rcl	30	rcl	70
1	31	3	71
)	32	arc	72
=	33	tan	73
goto	34	+/−	74
5	35	goto	75
6	36	0	76
÷	37	0	77
rcl	38		78
0	39		79

To find attenuation and phase change for angular frequency ω (or frequency f).



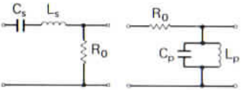
Low pass:
cut off frequency = ω_0,

deviation parameter, $V = \dfrac{\omega}{\omega_0}$



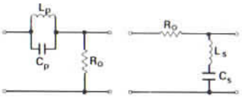
High pass:
cut off frequency = ω_0,

$V = -\dfrac{\omega_0}{\omega}$



Band pass:
upper cut off frequency = ω_2,
lower cut off frequency = ω_1,
centre frequency = $\omega_0 = \sqrt{\omega_1 \omega_2}$,

$$V = \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\left(\frac{\omega_0}{\omega_2 - \omega_1}\right)$$



Band stop:
upper pass frequency $= \omega_2$,
lower pass frequency $= \omega_1$
centre frequency $= \omega_0 = \sqrt{\omega_1 \omega_2}$

$$V = \frac{\dfrac{\omega_2 - \omega_1}{\omega_0}}{\dfrac{\omega_0}{\omega} - \dfrac{\omega}{\omega_0}}$$

Attenuation, A(dB)

$$= -20 \log \sqrt{1 + V^2}$$

Phase, $\phi = -$arc tan V

Pre-execution:

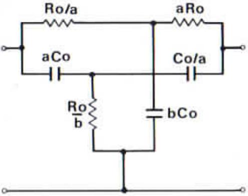
Store ω_0 and ω_1, ω_2 (if applicable) in memories 0, 1, 2 respectively.

Execution:

High pass: goto/0/8/ω/run/A/
run/ϕ
Low pass: goto/0/1/ω/run/A/
run/ϕ
Band pass: goto/1/7/ω/run/A/
run/ϕ
Band stop: goto/3/7/ω/run/A/
run/ϕ

TWIN T-NETWORK

KEY	#	KEY	#
HALT	00	+	40
sto	01	1	41
0	02	)	42
1/x	03	=	43
×	04	sto	44
stop	05	2	45
−	06	x^2	46
1/x	07	+	47
+	08	1	48
2	09	=	49
=	10	$\sqrt{x}$	50
1/x	11	log	51
×	12	×	52
2	13	2	53
+/−	14	0	54
=	15	+/−	55
$\sqrt{x}$	16	=	56
sto	17	stop	57
1	18	rcl	58
stop	19	2	59
+	20	arc	60
1/x	21	tan	61
=	22	+/−	62
stop	23	goto	63
÷	24	0	64
rcl	25	0	65
0	26		66
−	27		67
1/x	28		68
=	29		69
1/x	30		70
+/−	31		71
×	32		72
2	33		73
×	34		74
(	35		75
rcl	36		76
1	37		77
x^2	38		78
1/x	39		79



Design:

ω_0 = null frequency

ω_1 = lower cut-off frequency

$$C_0 R_0 = \frac{1}{\omega_0}$$

$$x_1 = \frac{\omega_1}{\omega_0}$$

$$a = \sqrt{\frac{2}{\frac{1}{x_1} - x_1 - 2}}$$

$$b = a + \frac{1}{a}$$

Performance: ω = test frequency

deviation parameter,

$$v = \frac{n}{\frac{1}{x} - x}$$

where $x = \frac{\omega}{\omega_0}$

$$n = \frac{2b}{a}$$

Attenuation A

$$= -20 \log \sqrt{1 + v^2} \text{ dB}$$

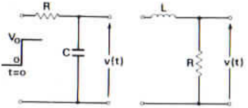
Phase ϕ = $-$arc tan v

Execution:

ω_0/run/ω_1/run/a/run/b/
ω/run/A/run/ϕ

SIMPLE L-R AND C-R CIRCUITS

KEY	#	KEY	#
HALT	00		40
+/−	01		41
e^x	02		42
+/−	03		43
+	04		44
1	05		45
=	06		46
goto	07		47
0	08		48
0	09		49
stop	10		50
+/−	11		51
+	12		52
1	13		53
=	14		54
ln	15		55
+/−	16		56
goto	17		57
1	18		58
0	19		59
stop	20		60
+/−	21		61
e^x	22		62
goto	23		63
2	24		64
0	25		65
stop	26		66
ln	27		67
+/−	28		68
goto	29		69
2	30		70
6	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79



Time constant $\tau = CR$ or $\frac{L}{R}$

Charge: $\frac{V(t)}{V_0} = 1 - e^{-t/\tau}$

Discharge: $\frac{V(t)}{V_0} = e^{-t/\tau}$

Execution:

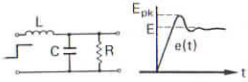
Charge (a) goto/0/1/$\frac{t}{\tau}$/run/$\frac{V}{V_0}$

(b) goto/1/1/$\frac{V}{V_0}$/run/$\frac{t}{\tau}$

Discharge (a) goto/2/1/$\frac{t}{\tau}$/run/$\frac{V}{V_0}$

(b) goto/2/7/$\frac{V}{V_0}$/run/$\frac{t}{\tau}$

DAMPING FACTOR AND OVERSHOOT



Overshoot $y = \frac{E_{pk}}{E} - 1$

Damping factor

$$K = -\frac{\ln y}{\sqrt{\pi^2 + (\ln y)^2}}$$

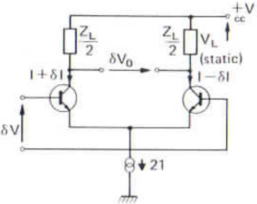
Execution:

$\frac{E_{pk}}{E}$/run/y/run/K

KEY	#	KEY	#
HALT	00		40
—	01		41
1	02		42
=	03		43
stop	04		44
ln	05		45
÷	06		46
(	07		47
x^2	08		48
+	09		49
0	10		50
π	11		51
x^2	12		52
)	13		53
$\sqrt{x}$	14		54
+/−	15		55
=	16		56
goto	17		57
0	18		58
0	19		59
	20		60
	21		61
	22		62
	23		63
	24		64
	25		65
	26		66
	27		67
	28		68
	29		69
	30		70
	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

KEY	#	KEY	#
HALT	00		40
×	01		41
8	02		42
./EE	03		43
6	04		44
1	05		45
7	06		46
1	07		47
5	08		48
./EE	09		49
5	10		50
+/−	11		51
=	12		52
sto	13		53
0	14		54
stop	15		55
÷	16		56
rcl	17		57
0	18		58
=	19		59
e^x	20		60
−	21		61
1	22		62
÷	23		63
(	24		64
+	25		65
2	26		66
)	27		67
=	28		68
goto	29		69
1	30		70
5	31		71
	32		72
	33		73
	34		74
	35		75
	36		76
	37		77
	38		78
	39		79

TRANSFER FUNCTION OF A LONG TAILED PAIR



k = Boltzmann's constant

T = Absolute temperature (= °C + 273.15)

q = Electronic charge

$$\frac{\delta I}{I} = \frac{\exp\left(q\frac{\delta V}{kT}\right) - 1}{\exp\left(q\frac{\delta V}{kT}\right) + 1}$$

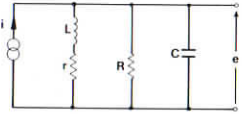
$\delta V_0 = Z_L \delta I$

and

$\delta V_0 = 2V_L \frac{\delta I}{I}$ if the load is resistive

KEY	#	KEY	#
HALT	00	$\sqrt{x}$	40
sto	01	×	41
0	02	rcl	42
×	03	1	43
stop	04	=	44
=	05	stop	45
1/x	06	rcl	46
$\sqrt{x}$	07	2	47
sto	08	×	48
1	09	rcl	49
÷	10	0	50
stop	11	+	51
×	12	rcl	52
rcl	13	0	53
0	14	x^2	54
=	15	×	55
sto	16	2	56
2	17	+	57
stop	18	1	58
÷	19	=	59
rcl	20	$\sqrt{x}$	60
1	21	−	61
÷	22	rcl	62
rcl	23	0	63
0	24	x^2	64
=	25	=	65
sto	26	$\sqrt{x}$	66
0	27	×	67
+	28	rcl	68
rcl	29	1	69
2	30	=	70
=	31	goto	71
1/x	32	0	72
stop	33	0	73
1	34		74
−	35		75
rcl	36		76
0	37		77
x^2	38		78
=	39		79

SINGLE TUNED CIRCUIT WITH LOSSES



This program finds Q and the resonant frequencies.

ω_0 = series resonant frequency

$$= \frac{1}{\sqrt{LC}}$$

ω_r = in-phase resonant frequency

$$= \omega_0 \sqrt{1 - \frac{r^2}{\omega_0^2 L^2}}$$

ω_p = parallel resonant frequency

$$= \omega_0 \left[\left(1 + 2\frac{r}{R} + 2\frac{r^2}{\omega_0 2_L 2} \right)^{1/2} - \frac{r^2}{\omega_0^2 L^2} \right]^{1/2}$$

Execution:

L/run/C/run/ω_0/R/run/r/run/Q/run/ω_r/run/ω_p

Pre-execution:

goto/0/1/T/run

Execution:

δV/run/$\frac{\delta I}{I}$

It is not necessary to repeat the pre-execution to repeat the execution.

	00		40
	01		41
	02		42
	03		43
	04		44
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	07		47
	08		48
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	10		50
	11		51
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	38		78
	39		79

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