Program Title TIMES OF ZENITH, SUNRISE AND SUNSET, TWILIGHT LIMITS

Contributor's Name RAYMOND BROECKX

Address Prieelstraat 12

City WILRIJK Country BELGIUM Postal Code 2610

Program Description, Equations, Variables

From the longitude LO, the latitude LA and the time zone z of the observer, this program finds, for a given date d|m|y, the times in hours, minutes and seconds, of highest sun, sunrise, beginning of twilight, sunset and end of twilight (in that order). Method:

(1) if m<3, change m to m+12 and y to y-1

(2) D=[365.25y]+[30.6(m+1)]+d-a-(LO/360) (a=723258.5)

(3) M=b+cD (b=357.7158, c=0.9856)

(4) K=d sinM + e sin2M (d=1/29.91, e=1/2865)

(5) S=(180K/PI) + f + gD (f=280.312, g=0.985647)

(6) $L=k \sin 2S - \frac{1}{2} k^2 \sin 4S$ ($k=\tan^2 \frac{i}{2}$, i=23.4419)

(7) X=PI + K - L (PI=π)

(8) x=180X/PI

(9) time of highest sun = $\frac{x-LO}{15}$ + z (hours)

(10) sin u = sin i sin S and cos u > 0

(11) ΔD = h/360, where cos h = (-m - sin LA sin u)/cos LA cos u
(m = sin 50' (OR) sin 6.5°)

(12) repeat (3)...(11) for D_1=D-ΔD, instead of D, find x' and h' instead ~~of x and h~~

(13) time of sunrise (OR) beginning of twilight = z + (x'-h'-LO)/15

Operating Limits and Warnings

(14) repeat (3)...(11) for D_2=D+ΔD instead of D, find x", h" for x, h

(15) time of sunset (OR) end of twilight = z + (x"+h"-LO)/15

Program Description 11

Sketch(es)

Sample Problem(s)

Observer at ANTWERP, LO=4°24', LA=51°13', time zone z=1
(Note: for longitudes WEST and latitudes SOUTH: CHS)
Having keyed these values in with LBLE, find times of highest sun, sunrise, beginning of twilight and sunset, end of twilight for November 17th, 1977.
Solution: press 17 ENT 11 ENT 1977 A and find:

highest sun	$12^h27^m18^s$
sunrise	8 01 38
beginning of twilight	7 21 21
sunset	16 52 19
end of twilight	17 32 40

Solution(s)

Reference(s) Günter SCHNELL's two-card programs 50036 and 50180 on the same subject

1 ZENITH SUNRISE SUNSET TWILIGHT 2

Magnetkarte

STEP	INSTRUCTIONS	INPUT DATA UNITS	KEYS	OUTPUT DATA UNITS
1	Enter program			
2	Key in observer's longitude LO,			
	latitude LA and time zone z	LO	ENT	
		LA	ENT	
		z	E	
3	Key in date d|m|y and find times	d	ENT	
	t_1 of highest sun	m	ENT	
	t_2 of sunrise	y	A	t_1
	t_3 of beginning of twilight			t_2
	t_4 of sunset			t_3
	t_5 of end of twilight			t_4
4	For another date, go to step 3			t_5
5	For another observer, go to step 2			

Note: if Error should be displayed, press C ent C RS, and disregard first coming result as non-existent

Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL A	11	Key in d, m, y here
	STO 6		
	↓		
	STO 5		
	↓		
	STO 4		
	1		
	STO+5		
	RCL 5		
010	4		
	x<y?	32 71	
	GTO 0		
	1		
	STO-6		
	1		
	2		
	STO+5		
	*LBL 0	00	
	3		
020	0		
	.		
	6		
	STOx5		
	3		
	6		
	5		
	.		
	2		
	5		
030	STOx6		
	RCL 6		
	INT		
	STO+4		
	RCL 5		
	INT		
	STO+4		
	7		
	2		
	3		
040	2		
	5		
	8		
	.		
	5		
	STO-4		
	RCL A 11		LO
	3		
	6		
	0		
050	STO D 14		
	:		
	STO-4		
	RCL 4		D
	B	XEQ B	
	RCL D 14		
	:		

STEP	KEY ENTRY	KEY CODE	COMMENTS
	STO 0		ΔD
	↓		
	C	XEQ C	
060	SF 0		
	D	XEQ D	
	CF 0		
	*LBL D	0	
	CF 1		
	SF 2		
	*LBL 1	1	
	RCL 4		
	RCL 0		
	F? 0		
070	CHS		
71	+	61	
72	B 12	31 22 12	
73	F? 0	35 71 00	
74	CHS	42	
75	+	61	
76	C 13	31 22 13	
77	SF 1	35 51 01	
78	F? 2	35 71 02	
79	GTO 1	22 01	
080	RTN	35 22	
	*LBL B		Subroutine to find x-LO and R
	STO 5		
	STO 6		
	.		
	9		
	8		
	5		
	6		
	4		
090	7		
	STOx6		
	DSP 4		
	RND		
	STOx5		
	3		
	5		
	7		
	.		
	7		
100	1		
	5		
	8		
	STO+5		M
	2		
	8		
	0		
	.		
	3		
	1		
110	2		
	STO+6		
	RCL 5		

REGISTERS

0	1	2	3	4	5	6	7	8	9
ΔD				d, D	m ...	y ...	used	used	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A 11	B 12	C 13	D 14	E	I
LO	LA	z	360		

51056 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	SIN		
	2		
	9		
	.		
	9		
	1		
	:		
120	RCL5		
	2		
	x		
	SIN		
	2		
	8		
	6		
	5		
	:		
	+		
	STO5		K
	→D	31 73	
	STO+6		S
	RCL6		
	2		
	x		
	SIN		
	2		
	3		
	.		
140	4		
	4		
	STO7		i
	2		
	:		
	TAN		
	x2		
	STO8		k
	x		
	RCL6		
	4		
	x		
	SIN		
	RCL8		
	x2		
	x		
	2		
	:		
	-		L
	STO-5		
160	PI	35 73	
	STO+5		X
	RCL5		
	→D	31 75	x
	RCLA		
	-		
	STO5		x-LO
	RCL6		
	SIN		

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL7		
170	SIN		
	x		sin w
	CHS		
	STO6		
	x2		
	1		
	-		
	CHS		
	√		
	STO7		
180	RCLB		cos w LA
	1		
	RECT L→R	31 72	
	STOx7		
184	x≥y	35 52	
	STOx6		
	6		
	.		
	5		
	ENT		
190	FRAC		
	→H	31 74	
	F?1		
	x==y	35 52	
	SIN		
	STO-6		
	RCL5		x-LO
	RCL6		and
	RCL7		
	:		
200	gARCCOS	32 63	h
	RTN		
	*LBLC		Subroutine to find $\frac{x}{15}+h$ from x (in HMS)
	1		
	5		
	:		
	RCLC		
	+		
	→HMS	32 79	
	-x-		
210	RTN		
	*LBLE		Initialize by keying in LO, LA and h
	STOC		
	↓		
	→H	31 74	
	STOB		
	↓		
	→H	31 74	
	STOA		
	RS		
220			

LABELS

A used	B used	C used	D used	E used
a	b	c	d	e
0 used	1 used	2	3	4
5	6	7	8	9

FLAGS

0	used
1	used
2	used
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐