



UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: March 2026

Module Number: CE5253

Module Name: Advanced Surveying(C-23)

[Three Hours]

[Answer all questions. Each question carries **TWELVE** marks]

All standard notations denote their regular meanings

Clearly state any assumptions made

- Q1. a) What are the three main sources of errors in a GNSS survey? [3.0 Marks]
- b) A specification states the error to be $\pm (3+5 \text{ ppm})$. Determine the total error in a 2 km measured line. [2.0 Marks]
- c) Briefly describe the three segments of Global Navigation Satellite Systems. [3.0 Marks]
- d) Briefly explain the GNSS post-processing static survey method. [4.0 Marks]
- Q2. a) A star was observed in the northern sky of Hapugala ($6^{\circ} 04' 52'' \text{ N}$, $80^{\circ} 11' 27'' \text{ E}$) when the star was crossing the meridian at 10:37:50 PM Sri Lankan standard time on 17 March 2026. Corrected altitude of the star during the crossing was $84^{\circ} 14' 40''$. Answer the following using the data given above. You are directed to refer to the extracts from the Star Almanac provided in Tables Q2-1 and Q2-2.
- i. Construct the semicircle with the diameter as the north-south plane of the observation and indicate the position of the star, zenith, and pole, and indicate relevant values. [2.0 Marks]
- ii. Determine the declination of the star. [2.0 Marks]
- iii. Determine the universal time when the star is crossing the meridian. [1.0 Mark]
- iv. Determine the Greenwich hour angle of the first point of Aires when the star is crossing the local meridian [2.0 Marks]
- v. Determine the Sidereal hour angle of the star. [2.0 Marks]
- vi. Identify the star. [1.0 Mark]
- b) Will the Sun be directly overhead at any point in Sri Lanka on 17 March 2025? Justify your answer based on the data provided in Tables Q2-1 and Q2-2 [2.0 Marks]

- Q3. a) Alnilam, a star in the constellation of Orion, was observed from a survey peg station P1 on the ground with a theodolite. The corrected altitude and the azimuth of Alnilam were $50^{\circ} 19' 42''$ and $80^{\circ} 43' 51''$ respectively. Answer the following using the data given above. You may use the extract of the Star Almanac given in Tables Q2-1 and Q2-2.
- Draw a 3D view of the northern celestial hemisphere for a viewer at a northerly latitude, as seen from the east, indicating the positions of pole (P), zenith (Z), and celestial equator (eq). Draw the path of a star that will not set.
 - Re-draw the 3D view of the northern celestial hemisphere stated in Q3. (a) i to form a spherical triangle with nodes as the pole, the zenith, and the star Alnilam. Indicate all relevant values of the triangle.
 - Using the spherical triangle formed in Q3.(a) ii, determine the hour angle of the star Alnilam with the northern arm of the local meridian (angle $Z\hat{P}A$).
 - Determine the latitude of the point of observation using the spherical triangle formed in Q3. (a) ii.
 - Draw a 2D view of the celestial hemisphere as seen from a point directly above the northern pole, indicating all relevant points, and determine the longitude of the point of observation.
 - Determine the local sidereal time of the observation
- [10.0 Marks]
- b) Determine the universal time (UT) when the star Alnilam reaches its highest altitude on that day.
- [2.0 Marks]
- Q4. Remote sensing is the art and science of obtaining information about an object or feature without physically contacting it.
- Briefly explain four civil engineering applications of remote sensing.
- [2.0 Marks]
- Distinguish between active remote sensing and passive remote sensing.
- [1.0 Mark]
- Using a neat sketch, list and describe all the relevant stages involved in the passive remote sensing process.
- [4.0 Marks]
- Explain the concept of an ideal remote sensing system and outline its fundamental components.
- [3.0 Marks]
- Discuss two advantages and two disadvantages of remote sensing.
- [2.0 Marks]

- Q5. a) Electromagnetic radiation (EMR) is used in the remote sensing process. When EMR travels through the atmosphere, the gases and particles present there cause scattering and absorption of electromagnetic radiation.
- Briefly explain the difference between scattering and absorption. [1.0 Mark]
 - Provide brief explanations of the three major types of scattering. [3.0 Marks]
 - Briefly explain the concept of the "atmospheric window" in remote sensing. [1.0 Mark]
- b) Briefly discuss the difference between geostationary satellites and sun-synchronous satellites. Highlight the field applications of each type of satellite. [2.0 Marks]
- c) The reflectance characteristics of Earth's surface features are expressed in terms of spectral reflectance, also known as surface albedo.
- Concrete surfaces have an albedo value of 30. What does this mean? [1.0 Mark]
 - Discuss the application of the "spectral reflectance curve" concept in remote sensing for identifying different Earth surface features. You may use an appropriate graph/sketch to support your answer. [4.0 Marks]

Equations, Figures, and Tables

$$L = \frac{\lambda \delta \phi}{\cos\left(\alpha_m + \frac{\delta \alpha}{2}\right)}$$

$$\frac{\sin A}{\sin(a)} = \frac{\sin P}{\sin(p)}$$

$$\delta \alpha = \Delta L \sin(\varphi_m)$$

$$GSrT = RA - \lambda_E$$

$$BC^2 = AB^2 + AC^2 - 2AB \times AC \cos A$$

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

$$\varphi_m = \frac{\varphi_A + \varphi_B}{2}$$

$$\alpha_m = \tan^{-1} \left[\frac{\mu \Delta L}{\lambda \delta \phi} \right]$$

$$H = H_o + r$$

$$\cos A = \frac{\cos a - \cos(b) \times \cos(c)}{\sin(b) \times \sin(c)}$$

$$\sin(A + B) = \sin(A)\cos(B) + \cos(A)\sin(B)$$

$$NDMI = \frac{Red - NIR}{Red + NIR}$$

Table Q2-1 Extracts from the Star Almanac for year 2026

March 17, 18, 19 UT (Tue., Wed., Thu.)

Aries			Venus			Mars			Jupiter			Saturn			Stars			
Tue	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec	SHA	Dec	SHA	Dec		
0	174°35.2	162°08.6	N04°15.9	191°22.8	S08°18.7	68°06.5	N22°56.2	170°22.1	S00°29.2	185°24.3	29.1	170°22.1	357°34.1	29°14.0	Alpheratz	357°34.1	29°14.0	
1	189°37.6	177°08.2	17.2	206°23.4	17.9	83°08.9	56.2	185°24.3	29.1	200°26.5	29.0	185°24.3	353°06.6	-42°09.9	Ankaa	353°06.6	-42°09.9	
2	204°40.1	192°07.9	18.4	221°24.0	17.1	98°11.3	56.2	200°26.5	29.0	215°28.6	28.9	200°26.5	349°30.5	56°40.9	Schedar	349°30.5	56°40.9	
3	219°42.6	207°07.5	19.7	236°24.7	16.4	113°13.7	56.2	215°28.6	28.9	230°30.8	28.7	215°28.6	348°46.6	-17°50.7	Diphda	348°46.6	-17°50.7	
4	234°45.0	222°07.1	21.0	251°25.3	15.6	128°16.1	56.2	230°30.8	28.7	245°33.0	28.6	230°30.8	335°19.9	-57°06.4	Achernar	335°19.9	-57°06.4	
5	249°47.5	237°06.8	22.3	266°25.9	14.9	143°18.5	56.2	245°33.0	28.6	260°35.2	S00°28.5	245°33.0	327°50.4	23°35.2	Hamal	327°50.4	23°35.2	
6	264°50.0	252°06.4	N04°23.5	281°26.6	S08°14.1	158°20.9	N22°56.1	260°35.2	S00°28.5	275°37.3	28.4	260°35.2	313°51.1	89°22.7	Polaris	313°51.1	89°22.7	
7	279°52.4	267°06.0	24.8	296°27.2	13.4	173°23.4	56.1	275°37.3	28.4	290°39.5	28.2	275°37.3	315°11.3	-40°12.2	Acamar	315°11.3	-40°12.2	
8	294°54.9	282°05.6	26.1	311°27.8	12.6	188°25.8	56.1	290°39.5	28.2	305°41.7	28.1	290°39.5	314°05.3	4°11.5	Menkar	314°05.3	4°11.5	
9	309°57.3	297°05.3	27.4	326°28.4	11.9	203°28.2	56.1	305°41.7	28.1	320°43.9	28.0	305°41.7	308°27.1	49°57.4	Mirfak	308°27.1	49°57.4	
10	324°59.8	312°04.9	28.6	341°29.1	11.1	218°30.6	56.1	320°43.9	28.0	335°46.1	27.9	320°43.9	290°38.6	16°33.7	Aldebaran	290°38.6	16°33.7	
11	340°02.3	327°04.5	29.9	356°29.7	10.4	233°33.0	56.1	335°46.1	27.9	350°48.2	S00°27.7	335°46.1	281°03.0	-8°10.4	Rigel	281°03.0	-8°10.4	
12	355°04.7	342°04.2	N04°31.2	11°30.3	S08°09.6	248°35.4	N22°56.1	350°48.2	S00°27.7	5°50.4	27.6	350°48.2	280°20.5	46°01.1	Capella	280°20.5	46°01.1	
13	10°07.2	357°03.8	32.5	26°31.0	08.9	263°37.8	56.1	5°50.4	27.6	20°52.6	27.5	5°50.4	278°21.8	6°22.3	Bellatrix	278°21.8	6°22.3	
14	25°09.7	12°03.4	33.7	41°31.6	08.1	278°40.2	56.1	20°52.6	27.5	35°54.8	27.4	20°52.6	Elnath	278°00.6	28°37.8	Elnath	278°00.6	28°37.8
15	40°12.1	27°03.0	35.0	56°32.2	07.3	293°42.6	56.1	35°54.8	27.4	50°57.0	27.3	35°54.8	275°36.7	-1°11.2	Alnilam	275°36.7	-1°11.2	
16	55°14.6	42°02.7	36.3	71°32.9	06.6	308°45.0	56.1	50°57.0	27.3	65°59.1	27.1	50°57.0	270°51.0	7°24.6	Betelgeuse	270°51.0	7°24.6	
17	70°17.1	57°02.3	37.5	86°33.5	05.8	323°47.4	56.1	65°59.1	27.1	81°01.3	S00°27.0	65°59.1	263°51.9	-52°42.8	Canopus	263°51.9	-52°42.8	
18	85°19.5	72°01.9	N04°38.8	101°34.1	S08°05.1	338°49.8	N22°56.1	81°01.3	S00°27.0	96°03.5	26.9	81°01.3	258°25.3	-16°45.3	Sirius	258°25.3	-16°45.3	
19	100°22.0	87°01.6	40.1	116°34.7	04.3	353°52.3	56.1	96°03.5	26.9	111°05.7	26.8	96°03.5	255°05.0	-29°00.7	Adhara	255°05.0	-29°00.7	
20	115°24.4	102°01.2	41.4	131°35.4	03.6	8°54.7	56.1	111°05.7	26.8	126°07.9	26.6	111°05.7	244°49.7	5°09.4	Procyon	244°49.7	5°09.4	
21	130°26.9	117°00.8	42.6	146°36.0	02.8	23°57.1	56.1	126°07.9	26.6	141°10.0	26.5	126°07.9	243°15.9	27°57.8	Pollux	243°15.9	27°57.8	
22	145°29.4	132°00.4	43.9	161°36.6	02.1	38°59.5	56.1	141°10.0	26.5	156°12.2	26.4	141°10.0	234°14.0	-59°35.8	Avior	234°14.0	-59°35.8	
23	160°31.8	147°00.1	45.2	176°37.3	01.3	54°01.9	56.1	156°12.2	26.4			156°12.2	222°45.3	-43°32.5	Suhail	222°45.3	-43°32.5	
Mer.pass. 12:20			ν -0.4' d 1.3' m -3.92			ν 0.6' d 0.8' m 1.16			ν 2.4' d 0.0' m -2.32			ν 2.2' d 0.1' m 0.94						

Wed	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec	SHA	Dec	SHA	Dec	
0	175°34.3	161°59.7	N04°46.4	191°37.9	S08°00.5	69°04.3	N22°56.1	171°14.4	S00°26.3	186°16.6	26.1	171°14.4	175°42.3	-17°41.4	Gienah	175°42.3	-17°41.4
1	190°36.8	176°59.3	47.7	206°38.5	07°59.8	84°06.7	56.1	186°16.6	26.1	201°18.8	26.0	186°16.6	172°58.4	-63°14.7	Acrux	172°58.4	-63°14.7
2	205°39.2	191°59.0	49.0	221°39.2	59.0	99°09.1	56.1	201°18.8	26.0	216°20.9	25.9	201°18.8	171°50.0	-57°15.7	Gacrux	171°50.0	-57°15.7
3	220°41.7	206°58.6	50.3	236°39.8	58.3	114°11.5	56.1	216°20.9	25.9	231°23.1	25.8	216°20.9	166°11.5	55°48.8	Alioth	166°11.5	55°48.8
4	235°44.2	221°58.2	51.5	251°40.4	57.5	129°13.9	56.1	231°23.1	25.8	246°25.3	25.7	231°23.1	158°21.0	-11°18.0	Spica	158°21.0	-11°18.0
5	250°46.6	236°57.8	52.8	266°41.1	56.8	144°16.3	56.1	246°25.3	25.7	261°27.5	S00°25.5	246°25.3	152°50.8	49°10.7	Alkaid	152°50.8	49°10.7
6	265°49.1	251°57.5	N04°54.1	281°41.7	S07°56.0	159°18.7	N22°56.1	261°27.5	S00°25.5	276°29.6	25.4	261°27.5	148°34.1	-60°29.9	Hadar	148°34.1	-60°29.9
7	280°51.6	266°57.1	55.3	296°42.3	55.2	174°21.1	56.1	276°29.6	25.4	291°31.8	25.3	276°29.6	147°56.1	-36°30.0	Menkent	147°56.1	-36°30.0
8	295°54.0	281°56.7	56.6	311°42.9	54.5	189°23.5	56.0	291°31.8	25.3	306°34.0	25.2	291°31.8	139°38.5	-60°56.5	Arcturus	145°46.7	19°02.5
9	310°56.5	296°56.4	57.9	326°43.6	53.7	204°25.9	56.0	306°34.0	25.2	321°36.2	25.0	306°34.0	137°19.0	74°02.5	Rigel Kent.	139°38.5	-60°56.5
10	325°58.9	311°56.0	04°59.1	341°44.2	53.0	219°28.3	56.0	321°36.2	25.0	336°38.4	24.9	321°36.2	136°54.7	-16°09.2	Kochab	137°19.0	74°02.5
11	341°01.4	326°55.6	05°00.4	356°44.8	52.2	234°30.7	56.0	336°38.4	24.9	351°40.5	S00°24.8	336°38.4	136°54.7	-16°09.2	Zuben'ubi	136°54.7	-16°09.2
12	356°03.9	341°55.2	N05°01.7	11°45.5	S07°51.5	249°33.1	N22°56.0	351°40.5	S00°24.8	6°42.7	24.7	351°40.5	126°02.7	26°37.3	Alphecca	126°02.7	26°37.3
13	11°06.3	356°54.9	02.9	26°46.1	50.7	264°35.5	56.0	6°42.7	24.7	21°44.9	24.5	6°42.7	112°14.5	-26°29.4	Antares	112°14.5	-26°29.4
14	26°08.8	11°54.5	04.2	41°46.7	49.9	279°37.9	56.0	21°44.9	24.5	36°47.1	24.4	21°44.9	107°07.8	-69°04.2	Atria	107°07.8	-69°04.2
15	41°11.3	26°54.1	05.5	56°47.4	49.2	294°40.3	56.0	36°47.1	24.4	51°49.3	24.3	36°47.1	102°01.6	-15°45.5	Sabik	102°01.6	-15°45.5
16	56°13.7	41°53.7	06.7	71°48.0	48.4	309°42.7	56.0	51°49.3	24.3	66°51.4	24.2	51°49.3	96°09.0	-37°07.3	Shaula	96°09.0	-37°07.3
17	71°16.2	56°53.4	08.0	86°48.6	47.7	324°45.1	56.0	66°51.4	24.2	81°53.6	S00°24.1	66°51.4	95°57.6	12°32.2	Rasalhague	95°57.6	12°32.2
18	86°18.7	71°53.0	N05°09.3	101°49.3	S07°46.9	339°47.5	N22°56.0	81°53.6	S00°24.1	96°55.8	23.9	81°53.6	90°41.7	51°28.7	Eltanin	90°41.7	51°28.7
19	101°21.1	86°52.6	10.5	116°49.9	46.2	354°49.9	56.0	96°55.8	23.9	111°58.0	23.8	96°55.8	83°31.3	-34°22.3	Kaus Aust.	83°31.3	-34°22.3
20	116°23.6	101°52.2	11.8	131°50.5	45.4	9°52.3	56.0	111°58.0	23.8	127°00.1	23.7	111°58.0	80°32.6	38°48.1	Vega	80°32.6	38°48.1
21	131°26.0	116°51.9	13.1	146°51.2	44.6	24°54.7	56.0	127°00.1	23.7	142°02.3	23.6	127°00.1	75°46.6	-26°15.8	Nunki	75°46.6	-26°15.8
22	146°28.5	131°51.5	14.3	161°51.8	43.9	39°57.1	56.0	142°02.3	23.6	157°04.5	23.4	142°02.3	61°59.2	8°56.1	Altair	61°59.2	8°56.1
23	161°31.0	146°51.1	15.6	176°52.4	43.1	54°59.5	56.0	157°04									

Table Q2-2 Extracts from the Star Almanac for year 2026

DUT1 = UT1-UTC = +0.0754 sec $\Delta T = TT-UT1 = +69.1086$ sec

2026 March 17 to Mar. 19 UT

h		Sun			Moon		
Tue	GHA	Dec	GHA	ν	Dec	d	HP
0	177°53.2	S01°25.8	201°49.4	12.8'	S12°03.8	14.6'	57.2'
1	192°53.4	24.8	216°21.3	12.9'	11°49.2	14.7'	57.3'
2	207°53.6	23.8	230°53.1	12.9'	11°34.5	14.7'	57.3'
3	222°53.8	22.8	245°25.0	12.9'	11°19.8	14.8'	57.3'
4	237°53.9	21.8	259°56.9	12.9'	11°05.0	14.9'	57.4'
5	252°54.1	20.9	274°28.8	12.9'	10°50.1	14.9'	57.4'
6	267°54.3	S01°19.9	289°00.8	12.9'	S10°35.2	15.0'	57.4'
7	282°54.5	18.9	303°32.7	13.0'	10°20.2	15.1'	57.5'
8	297°54.7	17.9	318°04.7	13.0'	10°05.1	15.1'	57.5'
9	312°54.8	16.9	332°36.6	13.0'	09°50.0	15.2'	57.5'
10	327°55.0	15.9	347°08.6	13.0'	09°34.8	15.2'	57.6'
11	342°55.2	14.9	1°40.6	13.0'	09°19.6	15.3'	57.6'
12	357°55.4	S01°13.9	16°12.6	13.0'	S09°04.3	15.4'	57.6'
13	12°55.6	12.9	30°44.7	13.0'	08°48.9	15.4'	57.6'
14	27°55.7	12.0	45°16.7	13.0'	08°33.5	15.5'	57.7'
15	42°55.9	11.0	59°48.7	13.0'	08°18.0	15.6'	57.7'
16	57°56.1	10.0	74°20.8	13.0'	08°02.4	15.6'	57.7'
17	72°56.3	09.0	88°52.8	13.1'	07°46.8	15.6'	57.8'
18	87°56.4	S01°08.0	103°24.9	13.1'	S07°31.2	15.7'	57.8'
19	102°56.6	07.0	117°56.9	13.1'	07°15.5	15.8'	57.8'
20	117°56.8	06.0	132°29.0	13.1'	06°59.7	15.8'	57.9'
21	132°57.0	05.0	147°01.0	13.1'	06°43.9	15.8'	57.9'
22	147°57.2	04.0	161°33.1	13.1'	06°28.1	15.9'	57.9'
23	162°57.3	03.1	176°05.2	13.1'	06°12.2	15.9'	57.9'
SD = 16.1'		d = 1.0'	SD = 15.6'				
Wed	GHA	Dec	GHA	ν	Dec	d	HP
0	177°57.5	S01°02.1	190°37.2	13.1'	S05°56.3	16.0'	58.0'
1	192°57.7	01.1	205°09.3	13.1'	05°40.3	16.0'	58.0'
2	207°57.9	01°00.1	219°41.3	13.0'	05°24.3	16.1'	58.0'
3	222°58.1	00°59.1	234°13.4	13.0'	05°08.2	16.1'	58.1'
4	237°58.2	58.1	248°45.4	13.0'	04°52.1	16.2'	58.1'
5	252°58.4	57.1	263°17.5	13.0'	04°35.9	16.2'	58.1'
6	267°58.6	S00°56.1	277°49.5	13.0'	S04°19.7	16.2'	58.1'
7	282°58.8	55.1	292°21.5	13.0'	04°03.5	16.2'	58.2'
8	297°59.0	54.2	306°53.5	13.0'	03°47.3	16.3'	58.2'
9	312°59.2	53.2	321°25.5	13.0'	03°31.0	16.3'	58.2'
10	327°59.3	52.2	335°57.5	13.0'	03°14.7	16.4'	58.3'
11	342°59.5	51.2	350°29.5	13.0'	02°58.3	16.4'	58.3'
12	357°59.7	S00°50.2	5°01.4	12.9'	S02°41.9	16.4'	58.3'
13	12°59.9	49.2	19°33.4	12.9'	02°25.5	16.4'	58.3'
14	28°00.1	48.2	34°05.3	12.9'	02°09.1	16.5'	58.4'
15	43°00.2	47.2	48°37.2	12.9'	01°52.6	16.5'	58.4'
16	58°00.4	46.2	63°09.1	12.9'	01°36.1	16.5'	58.4'
17	73°00.6	45.3	77°41.0	12.8'	01°19.6	16.5'	58.4'
18	88°00.8	S00°44.3	92°12.8	12.8'	S01°03.1	16.6'	58.5'
19	103°01.0	43.3	106°44.7	12.8'	00°46.5	16.5'	58.5'
20	118°01.1	42.3	121°16.5	12.8'	00°30.0	16.6'	58.5'
21	133°01.3	41.3	135°48.2	12.8'	S00°13.4	16.6'	58.6'
22	148°01.5	40.3	150°20.0	12.7'	N00°03.2	16.7'	58.6'
23	163°01.7	39.3	164°51.7	12.7'	00°19.9	16.6'	58.6'
SD = 16.1'		d = 1.0'	SD = 15.8'				
Thu	GHA	Dec	GHA	ν	Dec	d	HP
0	178°01.9	S00°38.3	179°23.4	12.7'	N00°36.5	16.6'	58.6'
1	193°02.1	37.3	193°55.1	12.6'	00°53.1	16.7'	58.7'
2	208°02.2	36.4	208°26.7	12.6'	01°09.8	16.6'	58.7'
3	223°02.4	35.4	222°58.3	12.6'	01°26.4	16.7'	58.7'
4	238°02.6	34.4	237°29.9	12.5'	01°43.1	16.7'	58.7'
5	253°02.8	33.4	252°01.4	12.5'	01°59.8	16.6'	58.7'
6	268°03.0	S00°32.4	266°32.9	12.5'	N02°16.4	16.7'	58.8'
7	283°03.1	31.4	281°04.4	12.4'	02°33.1	16.7'	58.8'
8	298°03.3	30.4	295°35.8	12.4'	02°49.8	16.7'	58.8'
9	313°03.5	29.4	310°07.2	12.4'	03°06.5	16.6'	58.8'
10	328°03.7	28.4	324°38.6	12.3'	03°23.1	16.7'	58.9'
11	343°03.9	27.4	339°09.9	12.3'	03°39.8	16.6'	58.9'
12	358°04.1	S00°26.5	353°41.2	12.2'	N03°56.4	16.7'	58.9'
13	13°04.2	25.5	8°12.4	12.2'	04°13.1	16.6'	58.9'
14	28°04.4	24.5	22°43.6	12.1'	04°29.7	16.7'	58.9'
15	43°04.6	23.5	37°14.7	12.1'	04°46.4	16.6'	59.0'
16	58°04.8	22.5	51°45.8	12.0'	05°03.0	16.6'	59.0'
17	73°05.0	21.5	66°16.8	12.0'	05°19.6	16.6'	59.0'
18	88°05.2	S00°20.5	80°47.8	11.9'	N05°36.2	16.6'	59.0'
19	103°05.3	19.5	95°18.7	11.9'	05°52.8	16.5'	59.1'
20	118°05.5	18.5	109°49.6	11.8'	06°09.3	16.6'	59.1'
21	133°05.7	17.6	124°20.5	11.8'	06°25.9	16.5'	59.1'
22	148°05.9	16.6	138°51.2	11.7'	06°42.4	16.5'	59.1'
23	163°06.1	15.6	153°22.0	11.7'	06°58.9	16.4'	59.1'
SD = 16.1'		d = 1.0'	SD = 16.0'				

Lat.	Twilight		Sunrise	Sunset	Twilight	
	Naut.	Civil			Civil	Naut.
N 72°	03:35	05:01	06:09	18:10	19:18	20:46
N 70°	03:52	05:08	06:09	18:10	19:11	20:28
68°	04:05	05:13	06:08	18:10	19:05	20:15
66°	04:15	05:17	06:08	18:10	19:01	20:04
64°	04:24	05:21	06:08	18:09	18:57	19:55
62°	04:31	05:24	06:08	18:09	18:54	19:47
60°	04:37	05:27	06:08	18:09	18:51	19:41
N 58°	04:42	05:29	06:08	18:10	18:49	19:35
56°	04:47	05:31	06:08	18:10	18:47	19:31
54°	04:51	05:32	06:08	18:10	18:45	19:27
52°	04:54	05:34	06:07	18:10	18:43	19:23
50°	04:57	05:35	06:07	18:10	18:42	19:20
45°	05:04	05:38	06:07	18:10	18:39	19:13
N 40°	05:08	05:40	06:07	18:10	18:37	19:08
35°	05:12	05:41	06:07	18:10	18:35	19:05
30°	05:15	05:43	06:06	18:10	18:34	19:02
20°	05:18	05:44	06:06	18:10	18:32	18:58
N 10°	05:20	05:44	06:05	18:11	18:32	18:56
0°	05:20	05:44	06:05	18:11	18:32	18:56
S 10°	05:19	05:43	06:04	18:12	18:33	18:57
20°	05:16	05:41	06:03	18:13	18:35	19:00
30°	05:10	05:38	06:02	18:13	18:37	19:05
35°	05:07	05:36	06:01	18:14	18:39	19:09
40°	05:02	05:34	06:01	18:15	18:42	19:13
45°	04:56	05:30	06:00	18:16	18:45	19:19
S 50°	04:48	05:26	05:58	18:17	18:49	19:27
52°	04:44	05:24	05:58	18:17	18:51	19:31
54°	04:40	05:22	05:57	18:18	18:53	19:35
56°	04:35	05:19	05:57	18:18	18:55	19:40
58°	04:29	05:16	05:56	18:19	18:58	19:45
S 60°	04:22	05:13	05:55	18:20	19:01	19:52

Lat.	Moonrise			Moonset		
	Tue	Wed	Thu	Tue	Wed	Thu
N 72°	07:04	06:24	05:48	15:13	17:34	19:56
N 70°	06:48	06:18	05:51	15:27	17:36	19:47
68°	06:35	06:13	05:53	15:37	17:37	19:39
66°	06:24	06:09	05:55	15:46	17:39	19:33
64°	06:15	06:06	05:56	15:54	17:40	19:28
62°	06:07	06:03	05:58	16:00	17:41	19:24
60°	06:01	06:00	05:59	16:05	17:42	19:20
N 58°	05:55	05:58	06:00	16:10	17:42	19:17
56°	05:49	05:55	06:01	16:14	17:43	19:14
54°	05:44	05:54	06:02	16:18	17:43	19:11
52°	05:40	05:52	06:03	16:21	17:44	19:09
50°	05:36	05:50	06:04	16:24	17:44	19:06
45°	05:27	05:47	06:06	16:31	17:45	19:02
N 40°	05:20	05:44	06:07	16:36	17:46	18:58
35°	05:14	05:41	06:08	16:41	17:47	18:54
30°	05:08	05:39	06:09	16:45	17:48	18:51
20°	04:59	05:35	06:11	16:52	17:49	18:46
N 10°	04:50	05:32	06:13	16:58	17:49	18:42
0°	04:42	05:28	06:15	17:04	17:50	18:37
S 10°	04:34	05:25	06:17	17:10	17:51	18:33
20°	04:25	05:22	06:18	17:16	17:52	18:29
30°	04:15	05:18	06:21	17:22	17:53	18:24
35°	04:10	05:15	06:22	17:26	17:53	18:21
40°	04:03	05:13	06:23	17:31	17:54	18:17
45°	03:56	05:10	06:25	17:36	17:54	18:14
S 50°	03:46	05:06	06:27	17:42	17:55	18:09
52°	03:42	05:04	06:28	17:44	17:56	18:07
54°	03:37	05:02	06:29	17:47	17:56	18:05
56°	03:32	05:00	06:30	17:50	17:56	18:02
58°	03:26	04:58	06:31	17:54	17:57	18:00
S 60°	03:19	04:56	06:33	17:58	17:57	17:56

Day	Sun		Mer. Pass	Moon		Age 28-0 5-0%
	Eqn. of Time 00 ^h mm:ss	12 ^h mm:ss		Upper Mer. Pass hh:mm	Lower Mer. Pass hh:mm	
17	08:27	08:19	12:08	10:53	23:16	
18	08:10	08:01	12:08	11:39	—	
19	07:53	07:44	12:08	12:26	00:03	