Answer Sheet

LABORATORY 1: EARTH-SUN RELATIONSHIPS AND INSOLATION RECEIPT

Student Name ________________________________

Student Number ______________________________

QUESTION 1

For a location at 50° North examine the graph below and answer the following questions:

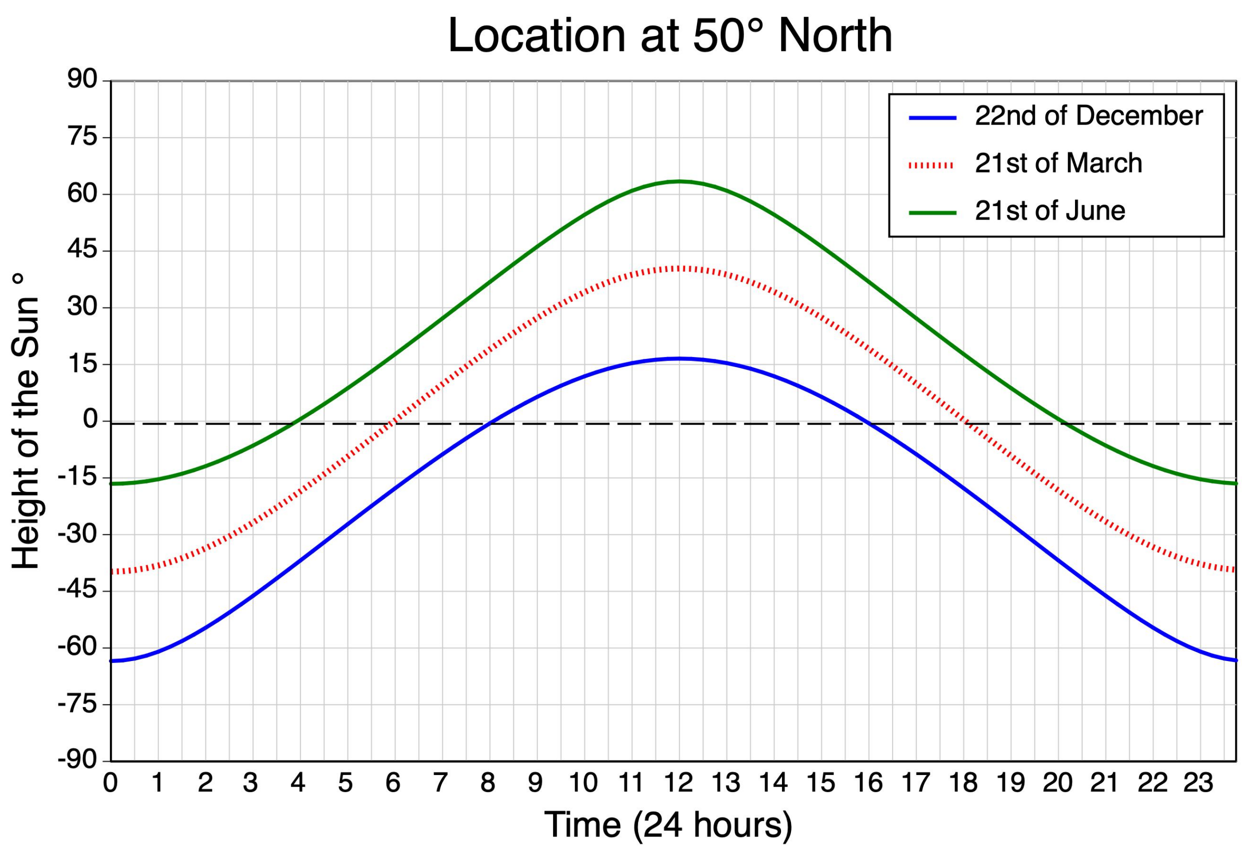

***Figure 1.9**. Height of the Sun above (+) or below (-) the horizon at different times during the day for December 22, March 21, and June 21 for a location found at 50° North. Image Copyright: Michael Pidwirny.*

For the date December 22 (December Solstice) -

1.1) At what time does the Sun first appear above the horizon (sunrise)?

A 8:09 AM.
B 6:00 AM.
C 3:51 AM.

1.2) At what time does the Sun have the greatest altitude?

A 11:45 AM.
B 12:00 AM (noon).
C 12:15 PM.

1.3) At what time does the Sun first appear below the horizon (sunset)?

A 8:09 PM.
B 6:00 PM.
C 3:51 PM.

1.4) On December 22, the North Pole is

A tilted 23.5 degrees towards the Sun.
B tilted 23.5 degrees away from the Sun.
C not tilted towards or away from the Sun (perpendicular).

For the date March 21 (March Equinox) -

1.5) At what time does the Sun first appear above the horizon (sunrise)?

A 8:09 AM.
B 6:00 AM.
C 3:51 AM.

1.6) At what time does the Sun have the greatest altitude?

A 11:45 AM.
B 12:00 AM (noon).
C 12:15 PM.

1.7) At what time does the Sun first appear below the horizon (sunset)?

A 8:09 PM.

B 6:00 PM.
C 3:51 PM.

1.8) On March 21, the North Pole is

A tilted 23.5 degrees towards the Sun.
B tilted 23.5 degrees away from the Sun.
C not tilted towards or away from the Sun (perpendicular).

For the date June 21 (June Solstice) -

1.9) At what time does the Sun first appear above the horizon (sunrise)?

A 8:09 AM.
B 6:00 AM.
C 3:51 AM.

1.10) At what time does the Sun have the greatest altitude?

A 11:45 AM.
B 12:00 AM (noon).
C 12:15 PM.

1.11) At what time does the Sun first appear below the horizon (sunset)?

A 8:09 PM.
B 6:00 PM.
C 3:51 PM.

1.12) On March 21, the North Pole is

A tilted 23.5 degrees towards the Sun.
B tilted 23.5 degrees away from the Sun.
C not tilted towards or away from the Sun (perpendicular).

1.13) On all of the dates above, the difference in the maximum height of the Sun between the June Solstice and December Solstice for 50° North is?

A 23.5 degrees.
B 47 degrees.
C 0 degrees.

QUESTION 2

For a location at 75° South examine the graph below and answer the following questions:

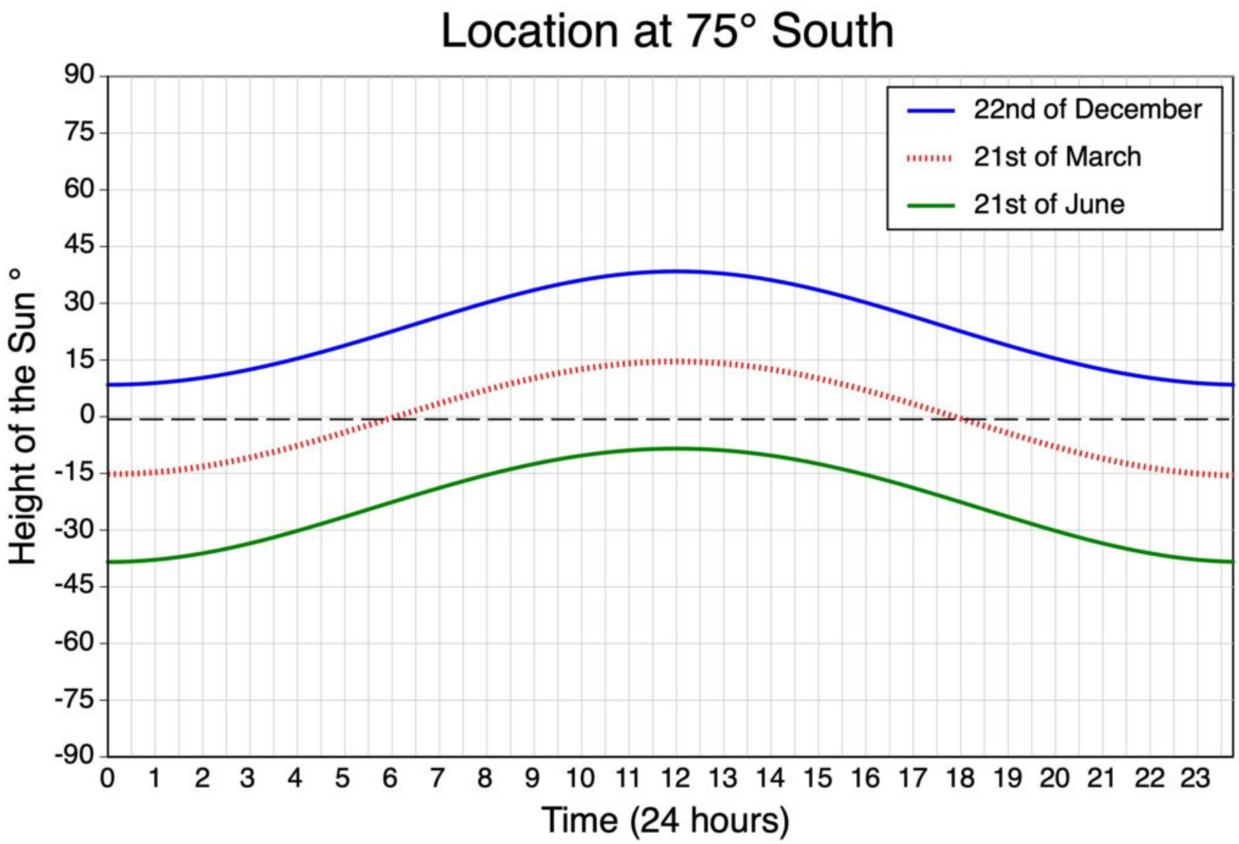

***Figure 1.10**. Height of the Sun above (+) or below (-) the horizon at different times during the day for December 22, March 21, and June 21 for a location found at 75° South. Image Copyright: Michael Pidwirny.*

For the date **December 22** (**December Solstice**) -

2.1) At what time does the Sun first appear above the horizon (sunrise)?

A The Sun is always above the horizon - 24 hours of day light.
B 6:00 AM.
C The Sun is always below the horizon - 24 hours of night.

2.2) At what time does the Sun have the greatest altitude?

A 6:00 AM.
B 12:00 AM (noon).
C 6:00 PM.

2.3) On December 22, the South Pole is

A tilted 23.5 degrees towards the Sun.
B tilted 23.5 degrees away from the Sun.
C not tilted towards or away from the Sun (perpendicular).

For the date **March 21** (**March Equinox**) -

2.4) At what time does the Sun first appear above the horizon (sunrise)?

A The Sun is always above the horizon - 24 hours of day light.
B 6:00 AM.
C The Sun is always below the horizon - 24 hours of night.

2.5) At what time does the Sun have the greatest altitude?

A 11:45 AM.
B 12:00 AM (noon).
C 12:15 PM.

2.6) At what time does the Sun first appear below the horizon (sunset)?

A 7:00 PM.
B 6:00 PM.
C 5:00 PM.

2.7) On March 21, the North Pole is

A tilted 23.5 degrees towards the Sun.
B tilted 23.5 degrees away from the Sun.
C not tilted towards or away from the Sun (perpendicular).

For the date **June 21** (**June Solstice**) -

2.8) At what time does the Sun first appear above the horizon (sunrise)?

A The Sun is always above the horizon - 24 hours of day light.
B 6:00 AM.
C The Sun is always below the horizon - 24 hours of night.

2.9) At what time does the Sun have the greatest altitude?

A 11:45 AM.
B 12:00 AM (noon) but its below the horizon.
C 12:15 PM.

2.10) On June 21, the North Pole is

A tilted 23.5 degrees towards the Sun.
B tilted 23.5 degrees away from the Sun.
C not tilted towards or away from the Sun (perpendicular).

2.11) On all of the dates above, the difference in the maximum height of the Sun between the June Solstice and December Solstice for 75° South is?

A 23.5 degrees.
B 47 degrees.
C 0 degrees.

QUESTION 3

For a location at 5° South examine the graph below and answer the following questions:

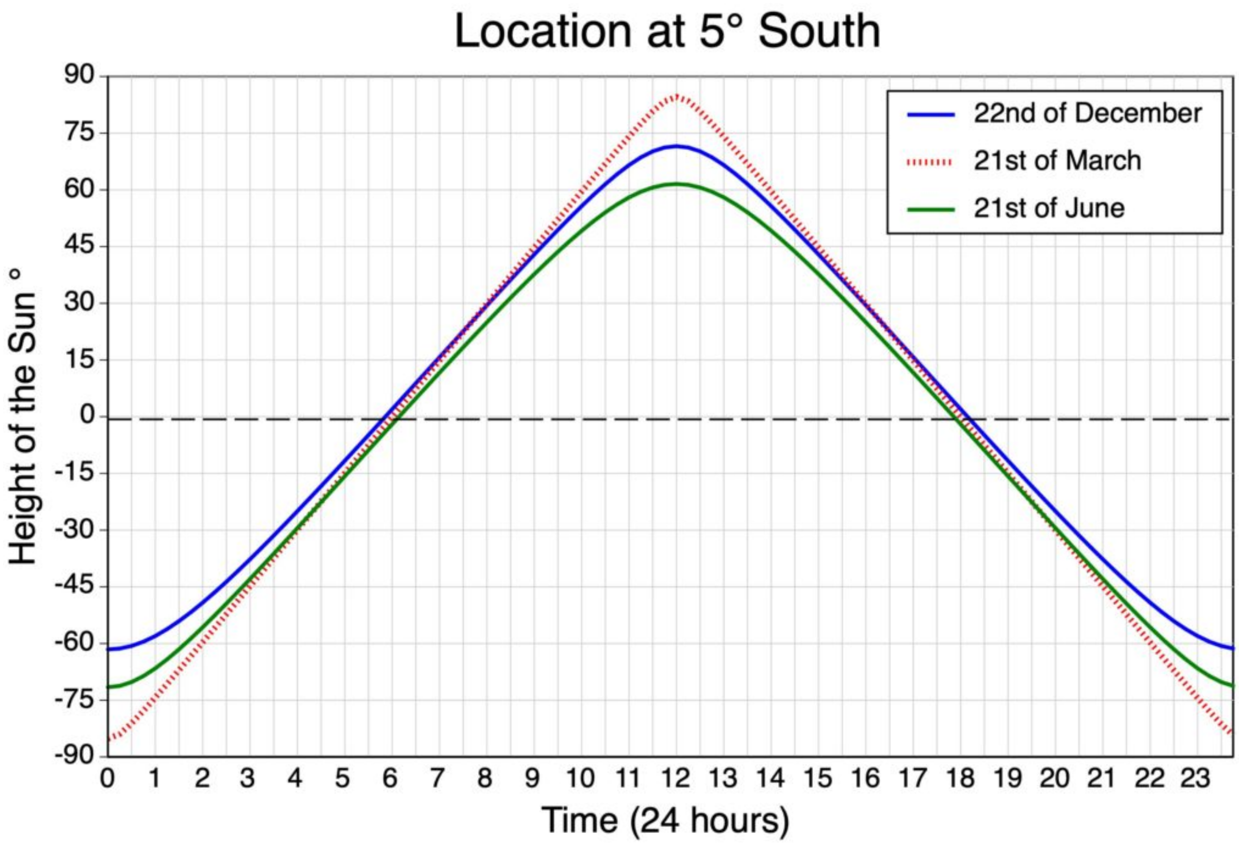

Figure 1.11**.** *Height of the Sun above (+) or below (-) the horizon at different times during the day for December 22, March 21, and June 21 for a location found at 5° South. Image Copyright: Michael Pidwirny.*

For the date **December 22** (**December Solstice**) -

3.1) At what time does the Sun first appear above the horizon (sunrise)?

A 5:45 AM.
B 6:00 AM.
C 6:15 AM.

3.2) At what time does the Sun have the greatest altitude?

A 11:45 AM.
B 12:00 AM (noon).
C 12:15 PM.

3.3) At 5° South, on December 22 day length is

A about 12 hours and 30 minutes long.
B exactly 12 hours long.
C about 11 hours and 30 minutes long.

For the date **March 21** (**March Equinox**) -

3.4) At 5° South, on March 21 day length is

A about 12 hours and 30 minutes long.
B exactly 12 hours long.
C about 11 hours and 30 minutes long.

3.5) At what time does the Sun have the greatest altitude?

A 11:45 AM.
B 12:00 AM (noon).
C 12:15 PM.

3.6) At what time does the Sun first appear below the horizon (sunset)?

A 5:45 PM.
B 6:00 PM.
C 6:15 PM.

3.7) On March 21, the North Pole is

A tilted 23.5 degrees towards the Sun.
B tilted 23.5 degrees away from the Sun.
C not tilted towards or away from the Sun (perpendicular).

For the date **June 21** (**June Solstice**) -

3.8) At 5° South, on June 22 day length is

A about 12 hours and 30 minutes long.
B exactly 12 hours long.
C about 11 hours and 30 minutes long.

3.9) At what time does the Sun first appear above the horizon (sunrise)?

A 5:45 AM.
B 6:00 AM.
C 6:15 AM.

QUESTION 4

Solar noon can be defined as the time during the day when the Sun is aligned with True North and True South Solar noon also represent the time when the Sun reaches its maximum altitude (which is usually measured as an angle) above the horizon. The following equation can be used to derive the Sun angle at solar noon:

$$\theta = 90° - \varphi \pm \delta$$

where θ (**theta**) is the noon Sun angle above the horizon, φ (**phi**) is the latitude, and δ (**delta**) is the solar declination; all values are in degrees.

This equation gives you the Sun angle when looking towards the Equator at noon. In tropical latitudes (between 23½° N and 23½° S), values of q greater than 90° may occur for some dates. When this occurs, the noonday Sun is actually "behind you" when looking towards the Equator. Under these circumstances, θ should be recalculated as:

$$\theta = 180 - (90° - \varphi \pm \delta)$$

Note: when using the equations above, treat all values of δ as positive when the location is tilted toward the Sun (summer half of the year), and negative when the location is tilted away from the Sun (winter half of the year).

The following YouTube video has some more interesting information regarding solar noon, please watch it:

https://www.youtube.com/watch?v=5wa2R4z1fss&t=3s

Figure 1.12. *A more in depth discussion of Sun angles and their calculation at solar noon from YouTube.*

We can determine the relative intensity of a particular Sun angle relative to 90° or directly overhead using the equation:

$$\textbf{Intensity} = \textbf{\textit{SIN}}\ \textbf{(A)}$$

where, **A** is the angle of incidence and ***SIN*** is the sine function found on most calculators. Using this equation, we can determine that an angle of 90° gives us a value of 1.00 or 100% (1.00 x 100).

Complete the missing measurements of Sun angle at solar noon (see declination values in **Table 1.1**), relative intensity of Solar Noon Sun angle to 90°, and day length (**Tables 1.2** and **1.3**) for the selected days for a **location at 50° North** and then answer the questions that follow.

Table 1.1. Approximate values of solar declination (δ, in integer degrees) for selected days of the year relative to the Northern Hemisphere (switch -/+ signs for Southern Hemisphere). On this table, day 81 = March Equinox, day 155 = June Solstice, day 264 = September Equinox, and day 355 = December Solstice.

Day	δ	Day	δ	Day	δ	Day	δ	Day	δ
5	-22.7	**81**	**0.0**	155	22.5	230	12.8	305	-15.3
10	-22.1	85	1.6	160	23.0	235	11.1	310	-16.8
15	-21.3	90	3.6	165	23.3	240	9.3	315	-18.2
20	-20.4	95	5.6	**170**	**23.5**	245	7.4	320	-19.4
25	-19.3	100	7.5	175	23.5	250	5.5	325	-20.5
30	-18.1	105	9.4	180	23.3	255	3.5	330	-21.4
35	-16.7	110	11.3	185	22.9	260	1.5	335	-22.1
40	-15.2	115	13.0	190	22.4	**264**	**0.0**	340	-22.7
45	-13.6	120	14.6	195	21.9	270	-2.6	345	-23.2
50	-12.0	125	16.1	200	20.9	275	-4.6	350	-23.4
55	-10.2	130	17.6	205	19.9	280	-6.5	**355**	**-23.5**
60	-8.3	135	18.8	210	18.7	285	-8.4	360	-23.4
65	-6.4	140	20.0	215	17.4	290	-10.3	365	-23.1
70	-4.4	145	21.0	220	16.0	295	-12.1		
75	-2.4	150	21.8	225	14.5	300	-13.8		

Note: We can determine the latitude where the Sun is perpendicular or directly overhead at solar noon directly from the declination values. Positive values of δ indicate this location is in the Northern Hemisphere, while negative values of δ indicate this location Southern Hemisphere. For example, on Day 50 the Sun is directly overhead at 12° S, while on Day 160 the Sun is directly overhead at 23° N.

Table 1.2. Length of time of daylight* for a given latitude in the Northern Hemisphere (all values are in hours: minutes).			
Latitude	**21st December**	**21st March** or **22nd September**	**21st June**
90° N	0:00	Sun at horizon	24:00
80° N	0:00	12:00	24:00
70° N	0:00	12:00	24:00
66½° N	0:00	12:00	24:00
60° N	5:33	12:00	18:27
50° N	7:42	12:00	16:18
40° N	9:08	12:00	14:52
30° N	10:04	12:00	13:56
23½° N	10:35	12:00	13:25
20° N	10:48	12:00	13:12
10° N	11:25	12:00	12:35
0°	12:00	12:00	12:00
*Daylight refers to the length of time between sunrise and sunset.			

Table 1.3. Length of time of daylight* for a given latitude in the Southern Hemisphere (all values are in hours: minutes).			
Latitude	**21st December**	**21st March** or **22nd September**	**21st June**
90° S	24:00	Sun at horizon	0:00
80° S	24:00	12:00	0:00
70° S	24:00	12:00	0:00
66½° S	24:00	12:00	0:00
60° S	18:27	12:00	5:33
50° S	16:18	12:00	7:42
40° S	14:52	12:00	9:08
30° S	13:56	12:00	10:04
23½° S	13:25	12:00	10:35
20° S	13:12	12:00	10:48
10° S	12:35	12:00	11:25
0°	12:00	12:00	12:00
*Daylight refers to the length of time between sunrise and sunset.			

4.1) For January 15 (day 15) Sun Angle at Solar Noon = 18.7 degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 8 hours and 15 minutes.

4.2) For January 30 (day 30) Sun Angle at Solar Noon = degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 8 hours and 58 minutes.

4.3) For March 1 (day 60) Sun Angle at Solar Noon = 31.7 degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 10 hours and 26 minutes.

4.4) For March 21 (day 80) Sun Angle at Solar Noon = ______ degrees; the Relative Intensity of Solar Noon Sun Angle = 64%; and Day Length = 12 hours and 0 minutes.

4.5) For April 20 (day 110) Sun Angle at Solar Noon = 51.3 degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 13 hours and 46 minutes.

4.6) For May 20 (day 140) Sun Angle at Solar Noon = ______ degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 15 hours and 23 minutes.

4.7) For June 21 (day 140) Sun Angle at Solar Noon = ______ degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = ______ hours and ______ minutes.

4.8) For August 23 (day 235) Sun Angle at Solar Noon = ______ degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 13 hours and 55 minutes.

4.9) For September 22 (day 265) Sun Angle at Solar Noon = ______ degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = ______ hours and ______ minutes.

4.10) For October 22 (day 295) Sun Angle at Solar Noon = ______ degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 10 hours and 26 minutes.

4.11) For December 22 (day 356) Sun Angle at Solar Noon = ______ degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = ______ hours and ______ minutes.

4.12) For December 31 (day 365) Sun Angle at Solar Noon = 16.9 degrees; the Relative Intensity of Solar Noon Sun Angle = ______ %; and Day Length = 7 hours and 55 minutes.

4.13) What progression of seasons are we observing for this location from December 31 to June 21?

> **A** Winter > Spring > Summer.
> **B** Summer > Fall > Winter.
> **C** Spring > Summer > Fall.

4.14) Describe what happens to the relative intensity of solar insolation at solar noon from June 21 to December 22.

> **A** It increases.
> **B** It decreases.
> **C** Stays the same.

QUESTION 5

5.1) During the June Solstice at Solar Noon

The Sun is directly overhead (90 degrees) at ______ degrees ______ (North or South).

The Sun is at 66.5 degrees above the horizon at degrees ______ North and the ______ (name place).

The Sun is at the horizon at ______ degrees ______ (North or South).

5.2) During the December Solstice at Solar Noon

The Sun is directly overhead (90 degrees) at ______ degrees ______ (North or South).

The Sun is at 66.5 degrees above the horizon at ______ degrees South and the ______ (name place).

The Sun is at the horizon at ______ degrees ______ (North or South).

5.3) During the Equinoxes at Solar Noon

The Sun is directly overhead (90 degrees) at the ______ (name place).

The Sun is at 66.5 degrees above the horizon at ______ degrees South and at ______ degrees North.

The Sun is at 10 degrees above the horizon at ______ degrees North and ______ degrees South.

QUESTION 6

So far in this lab we have discovered four important facts:

1. The height of the Sun varies on a daily cycle with maximum Sun height occurring at solar noon. These daily cycles are due to Earth rotation.
2. The height of the Sun also varies annually because of changes in the position of the Earth's axis relative to the Sun.
3. Changes in the position of the Earth's axis relative to the Sun also influence day lengths, except for locations on the Equator.
4. The potential intensity of the Sun's insolation is influenced by the angle of incidence.

Using this knowledge and the potential insolation data found in **Table 1.4** answer the following questions.

Table 1.4. Theoretical insolation received on a horizontal surface without the influence of the atmosphere at various latitudes on four dates (all values are 24 hr averages, in Wm^{-2}).

	March 21		June 21		Sept. 22		Dec. 21	
Latitude	North	South	North	South	North	South	North	South
90°	0	0	527	0	0	0	0	560
80°	76	76	520	0	75	75	0	552
70°	150	150	496	0	148	148	0	526
60°	219	219	480	23	217	217	24	509
50°	280	280	484	81	278	278	86	515
40°	334	334	485	147	331	331	156	516
30°	378	378	477	213	374	374	227	507
20°	410	410	458	278	406	406	295	487
10°	430	430	428	336	426	426	357	454
0°	437		387		433		411	

6.1) How much insolation is received at 20° North on December 22?

___________ Watts per meter square.

6.2) How much insolation is received at 20° South on June 21?

___________ Watts per meter square.

6.3) What factors account for the difference in insolation received in questions 6.1 and 6.2? Review Figures 1.2 and 1.3 before answering this question. (select one or more correct responses)

A The Earth's elliptical orbit causes our planet to be closer to the Sun around Perihelion.
B Differences in day length.
C Differences in Sun angles.

6.4) How much insolation is received at 60° North on December 22?

__________ Watts per meter square.

6.5) How much insolation is received at the equator (0°) on December 22?

__________ Watts per meter square.

6.6) What factors account for the difference in insolation received in questions 6.4 and 6.5? Review Figures 1.2 and 1.3 before answering this question. (select one or more correct responses)

A The Earth's elliptical orbit causes our planet to be closer to the Sun around Perihelion.
B Differences in day length.
C Differences in Sun angles.

6.7) How much insolation is received at the equator (0°) on September 23?

__________ Watts per meter square.

6.8) How much insolation is received at 60° North on September 23?

__________ Watts per meter square.

6.9) What factors account for the difference in insolation received in questions 6.7 and 6.8? Review Figures 1.2 and 1.3 before answering this question. (select one or more correct responses)

A The Earth's elliptical orbit causes our planet to be closer to the Sun around Perihelion.
B Differences in day length.
C Differences in Sun angles.