SIERRA COLLEGE OBSERVATIONAL ASTRONOMY LABORATORY EXERCISE		
NUMBER VI.A.	**TITLE: The Sundial Project**	
DATE- **DAY-** **LOCATION**	**PRINT NAME/S AND INITIAL BELOW:**	**GROUP** ☐

INTRODUCTION

Each student in Astronomy 11 is expected to design and build a sundial. The sundial may be done individually or as part of a group effort. The completed sundial is due as indicated by the instructor. Check with the instructor prior to this date for any questions on the design or function of the sundial. The sundial is worth 20 points with the points divided between: 1) Technical Accuracy [10 points]; 2) Quality of Written Report [5 points]; and 3) Aesthetic Appearance [5 points].

DESIGN AND CONSTRUCTION POINTERS

The instructor will give a brief lecture on the technical features of the sundial construction. The student is then expected to incorporate these technical features in an original and aesthetic design. There are sundial models on display in the laboratory to help spark an idea or two. In any case, the primary technical features to pay close attention to are as follows:

- Be sure the sundial base is level
- Be sure the style is made of thin but sturdy material
- Be sure style angle is equal to local latitude
- Be sure the face of the style is perpendicular to the sundial base
- Be sure style base is oriented North-South (the style edge points toward the North Star)
- Be sure the vertices of all the hour lines are located at the style vertex
- Be sure the hour angles are measured from the noon line at the style base
- Be sure the hour lines are symmetrical to both the E-W and N-S lines of the sundial

WRITTEN REPORT

Each student must individually submit a written report addressing the following points regarding the proper use and set-up of a sundial. Each report must be typed (double spaced).

- Does the base of the sundial have to be level in order to operate properly?
- In what direction must the tip of the style or gnomon point for a properly oriented sundial?
- The angle of the style to the plate of a conventional sundial must equal the observer's _____?

- Give three reasons why the sundial time (local apparent solar time) does not always agree exactly with the Pacific Standard Time (PST). Assume the sundial is constructed properly and set up correctly.
- Determine what time (PST) a properly constructed and oriented sundial will register 2 PM on December 17.
- On what date(s) would a sundial located in Rocklin, CA, agree (within 30 seconds) with an accurately set local clock (PST)?
- If your sundial was part of a group effort, what part did you play in its design and construction? If you were not part of a group effort, please indicate this in your report.

ADDITIONAL SUNDIAL SPECIFICATIONS

- Constructed for: local latitude = **39^{O}** longitude = **121^{O}**
- Hour range must be from 5 AM to 7 PM local apparent solar time

CONSTRUCTING THE HOUR LINES – THE 'TRIG' METHOD

- Sundial may be constructed for a horizontal or vertical base. For a horizontal base, the equation for the hour lines is:

$$\tan(A_t) = \tan(t) \bullet \sin(L)$$

- For a vertical plate sundial the equation for the hour lines is:

$$\tan(A_t) = \tan(t) \bullet \cos(L)$$

where A_t is the angle from the style base (North-South Line) to the hour of interest, **t**. The hour of interest (**t**) can be expressed in hours or degrees (*15 degrees for each hour* before or after noon), and **L** is the sundial's latitude. **Caution**: When using a calculator, be sure the degree mode is set ***ON*.** Complete the table below.

TIME	t (hrs)	t (°)	tan(t) • sin(L)	A_t
11 AM / 1 PM				
10 AM / 2 PM				
9 AM / 3 PM				
8 AM / 4 PM				
7 AM / 5 PM				
6 AM / 6 PM				
5 AM / 7 PM				

CONSTRUCTING THE HOUR LINES – THE GEOMETRIC METHOD

For this method, you will need a straight edge, drafting compass, protractor, sharpened pencil, and an 11" x 17" sheet of paper. In the following steps, refer to the diagram on the back of this page.

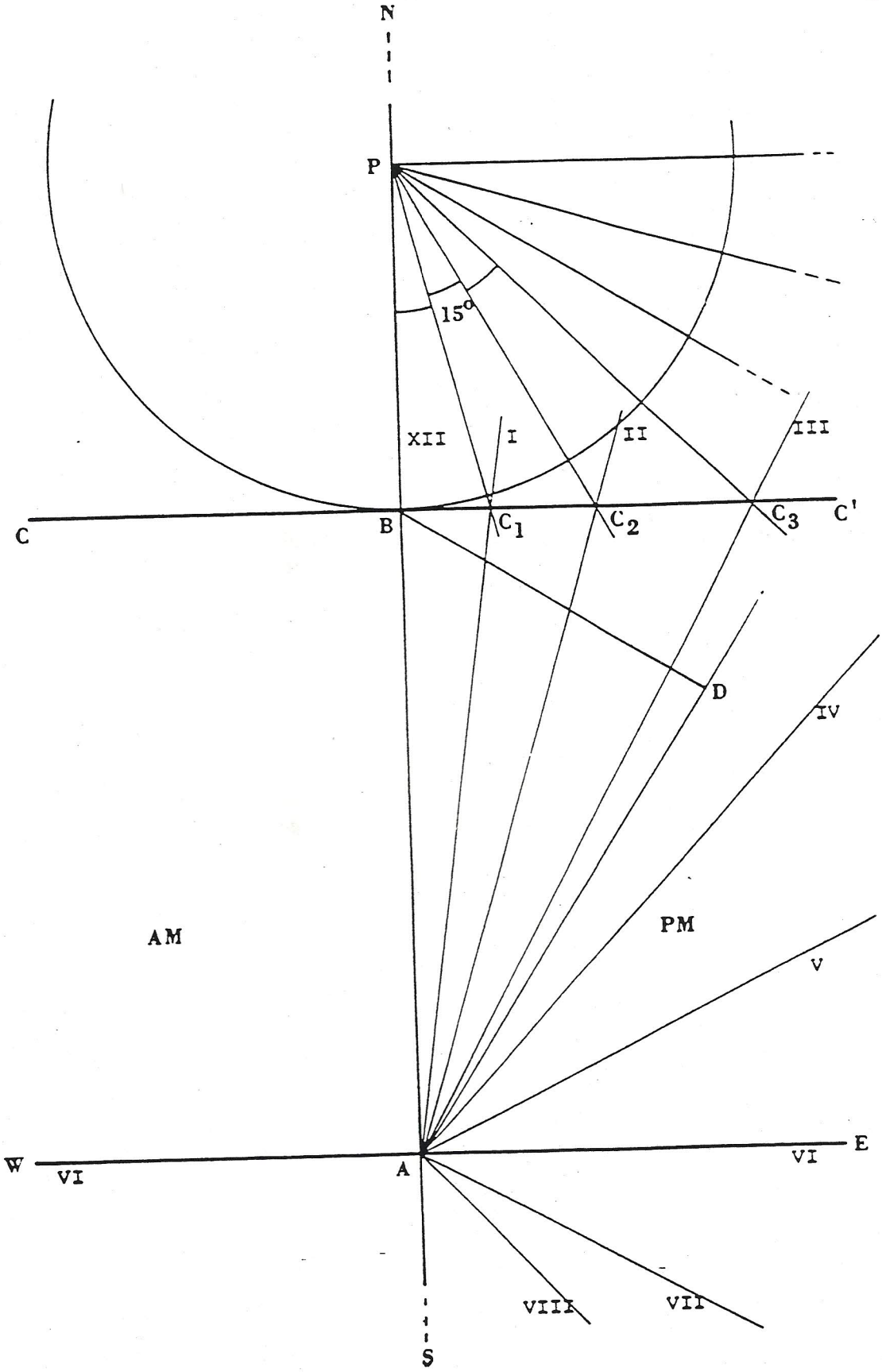
- In the center of the 11x17 paper or base of your sundial, draw a vertical line, **NS**, to represent the north-south line. This will be the meridian and direction of the shadow at local apparent noon.
- Near the bottom of **NS**, draw a line through point **A** at right angles. This is the east-west line, **EW**, and will be marked 6a.m. and 6p.m., since it marks the direction of the shadows at those times.
- Select some point, **B**, on **NS** and draw another line at right angles to **NS**. Call it **CC'**.
- Draw a line, **AD**, from point **A** which makes an angle **BAD = L** with the line **NS**, where **L** is the latitude of the sundial. Then drop a perpendicular **BD** from **B** to the line **AD**.
- Lay off a distance, **BP**, on line **NS** equal to the distance **BD**. **P** represents the celestial pole.
- Draw a circle (or half-circle) with **P** as its center. Mark off on the circle points which are 15^{o} apart; that is, one hour apart. Draw radii of the circle from **P** through the points marked off on the arc. Where they intersect the line **CC**', mark the points $\mathbf{C_1}$, $\mathbf{C_2}$, $\mathbf{C_3}$, - - -.
- Connect each of the points $\mathbf{C_1}$, $\mathbf{C_2}$, $\mathbf{C_3}$, - - - with the point **A**. The angles $\mathbf{BAC_1}$, $\mathbf{BAC_2}$, $\mathbf{BAC_3}$, - - - are the **At** angles in the trig formula and table on the previous page. This array of lines marks the position of the shadows for the afternoon hours (using Roman Numerals) as shown in the figure on the next page. The morning hours can be marked similarly at the same angles on the left side of **AB** and marked accordingly, **XI**, **X**, **IX**, - - -. In the figure, only the first three lines were drawn by construction, since the paper was not large enough to draw the lines for the later hours. The later hours must be drawn using a larger sheet of paper, like 11" x 17" provided at your request.

CORRECTIONS TO THE SUNDIAL

Adjacent to each date below is the corresponding Standard Time a sundial would register NOON. As a further correction for longitude, add 4 minutes for every degree your sundial is located west of the Standard Time meridian. For any other time of day, simply add or subtract the appropriate number of hours and minutes from the NOON time.

Example: What time (PST) would the shadow produced by a sundial located at 122° W longitude register 4 PM on July 10? Solution: By the table below, sundial noon occurs at $12^{h}05^{m}$. Add 8 minutes to correct for local longitude. We now have sundial noon occurring at $12^{h}13^{m}$. Now add 4 hours for time of day. Thus, at 4:13 PM PST, the sundial will register exactly 4 PM.

Jan	1	12h 03m 32s	Apr	1	12h 03m 56s	Jul	5	12h 04m 31s	Oct	3	11h 49m 06s
	6	12h 05m 49s		6	12h 02m 28s		10	12h 05m 18s		8	11h 47m 37s
	11	12h 07m 54s		11	12h 01m 05s		15	12h 05m 55s		13	11h 46m 18s
	16	12h 09m 44s		16	11h 59m 50s		20	12h 06m 19s		18	11h 45m 13s
	21	12h 11m 17s		21	11h 58m 43s		25	12h 06m 30s		23	11h 44m 23s
	26	12h 12m 32s		26	11h 57m 49s		30	12h 06m 26s		28	11h 43m 50s
	31	12h 13m 27s									
			May	1	11h 57m 06s	Aug	4	12h 06m 06s	Nov	2	11h 43m 36s
Feb	5	12h 14m 01s		6	11h 56m 36s		9	12h 05m 31s		7	11h 43m 41s
	10	12h 14m 15s		11	11h 56m 20s		14	12h 04m 42s		12	11h 44m 08s
	15	12h 14m 09s		16	11h 56m 18s		19	12h 03m 39s		17	11h 44m 56s
	20	12h 13m 46s		21	11h 56m 31s		24	12h 02m 25s		22	11h 46m 06s
	25	12h 13m 06s		26	11h 56m 58s		29	12h 01m 00s		27	11h 47m 34s
				31	11h 57m 36s						
Mar	2	12h 12m 12s				Sep	3	11h 59m 25s	Dec	2	11h 49m 21s
	7	12h 11m 06s	Jun	5	11h 58m 24s		8	11h 57m 44s		7	11h 51m 22s
	12	12h 09m 49s		10	11h 59m 21s		13	11h 56m 00s		12	11h 53m 37s
	17	12h 08m 25s		15	12h 00m 22s		18	11h 54m 13s		17	11h 56m 01s
	22	12h 05m 57s		20	12h 01m 28s		23	11h 52m 27s		22	11h 58m 30s
	27	12h 05m 26s		25	12h 02m 33s		28	11h 50m 44s		27	12h 00m 59s
				30	12h 03m 35s					32	12h 03m 24s



Construction of Lines on a Sundial Plate