SHRINE ASSIGNMENT

One of the best known features of the Shrine of Remembrance in Melbourne is the beam of sunlight that falls on the Stone of Remembrance on Armistice day at the 11th hour of the 11th day of the 11th month each year (clouds permitting); commemorating the moment of the end of the First World War in 1918.

Each year the Shrine trustees arrange a Remembrance Day service, but since the introduction of daylight saving in the summer of 1971-72, the natural event of the beam of sunlight passing across the Stone of Remembrance occurs at 12 pm rather than at the commemoration time of 11 am. The problem caused by daylight saving, was brought to the then Department of Surveying, RMIT by Mr Frank Doolan on behalf of the Trustees in 1975. Mr Doolan and Julius Knight of the surveying firm Doolan & Goodchild were the construction surveyors for the Shrine in the early 1930's and together with the government astronomer J. M. Baldwin, were responsible for the calculations and surveying to ensure that the apertures in the ceiling and outer wall, and the Stone of Remembrance, all lay in the correct light path at the appointed hour.

The problem and its solution fell naturally at the feet of the ever-resourceful Frank Johnston; a former member of staff and now retired who devised a solution consisting of two mirrors; one facing downwards in the outer aperture of the roof of the Shrine, and a second inclined mirror on a low pillar on the upper walkway out of public view. The Sun at 11 am daylight saving time (11h east of UT) is reflected by the inclined mirror up onto the plane mirror in the outer aperture to appear as it would at 11 am standard time (10h east of UT).

You are required to determine the DIP and STRIKE of the inclined mirror for 11 am on the 11th November 2010.

The latitude and longitude of the Shrine can be taken as: $\varphi = -37^\circ\ 49'\ 55''$ and $\lambda = 144^\circ\ 58'\ 20''$

A short description of the 'bending the beam' problem is attached as well as several images that may be useful in understanding the problem.

BENDING THE BEAM

One of the best known features of the Shrine of Remembrance in Melbourne is the beam of sunlight that falls on the Stone of Remembrance on Armistice day at the 11th hour of the 11th day of the 11th month each year (clouds permitting); commemorating the moment of the end of the First World War in 1918.

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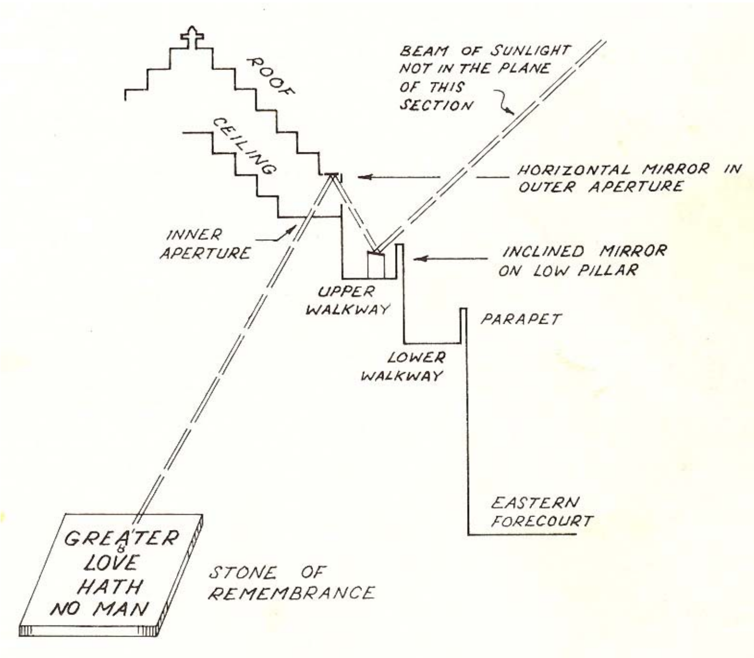
The problem and its solution fell naturally at the feet of the ever-resourceful Frank Johnston; newly arrived at the Department from National Mapping. An initial idea was to erect a mirror on the outer wall of the Shrine that would deflect the sun directly onto the correct line. But calculations showed that such a mirror would need to be over a metre in length and would be difficult to mount and an unsightly protuberance. So after some thought, Frank realized that by placing a horizontal mirror in the outer aperture facing down, and a second inclined mirror on a low pillar – on the upper walkway out of public view – the desired reflection could be achieved. The diagram shows a vertical section through the Shrine that contains the light beam and its reflection from the horizontal mirror in the outer aperture and the inclined mirror.



The inclined mirror must be oriented to deflect a beam of sunlight via the horizontal mirror onto the Stone of Remembrance at the appointed time. The inclined mirror can be set if the azimuth and zenith distance of the normal to the mirror are known. These can be computed from spherical trigonometry knowing the azimuth and zenith distance of the sun at 11 and 12 o'clock daylight saving time. The normal of the mirror will pass through a point midway along the great circle connecting the two positions of the sun on the unit sphere after allowing for the reflection of the 12 o'clock position.

The "Shrine Mirror Problem" was a common assignment task in astronomy at RMIT and several student submissions are still discussed amongst staff; one in particular by Andrew Thomson (1987) that is a model of vector economy avoiding spherical trigonometry entirely.

Of course, calculating the orientation of the mirror and actually setting the mirror are two entirely different problems. And Frank Johnston solved the setting problem in a typically practical manner using a pentaprism and the autocollimation method. (A pentaprism is a theodolite attachment that "turns" the line of sight through 90 degrees and autocollimation is where the reflection of the theodolite in a mirror is used as a target.) The pentaprism line of sight must first be set in a vertical plane by sighting an object directly; and then sighting the same object with the pentaprism fitted without moving the horizontal circle of the theodolite. Once this has been done the required azimuth and zenith distance of the normal are set and the mirror orientated by centreing the reflection of the pentaprism in the field of view.

This method works very well and for the past thirty-four years Frank Johnston has dutifully set the inclined mirror (usually in the week preceding the event) and on the 11th of November this year (and all the others) placed the horizontal mirror in the outer aperture of the Shrine roof prior to the service.

Interestingly, only a few invited dignitaries get to see the actual event, as the Stone of Remembrance is set within a small stone enclosure within the Shrine. But perched in the space between the inner and outer roofs of the Shrine; Frank and whoever may be assisting him, have a birds-eye view of proceeding through the inner aperture. One year during the transit of the sun over the Stone, Frank whispered forcefully "Damn, a cloud's come over and the sun's gone" but it was shining strongly on the back of his head as he was leaning forward for a better view. Traps for young players.

Rod Deakin

November, 2009

NOTE: This is a revised version of *Bending the Beam* that first appeared in Traverse 104, November 1987 written by Frank Johnston. And in typical Frank fashion, he found it difficult to mention himself. I hope I have corrected things. I have been Frank's understudy for almost 30 years and was his student at RMIT in the mid 1970's. (Traverse is the news Bulletin of the Institution of Surveyors, Victoria)

NOTES ON SETTING THE SHRINE MIRROR

Equipment required: T2 (old style) + tribrach + mirrors + tripod
Pentaprism and counterweight

1. Unlock cover and unscrew locking pin to remove circular copper cover.
2. Set the T2 on the tripod on the south side of mirror close to the parapet wall so that when the pentaprism is attached to the theodolite and the telescope is near horizontal, the pentaprism is close to vertically above mirror.
3. Sight to the main spire of St Pauls' cathedral (almost due north of the Shrine) and set the azimuth.
4. Select a mark X on the pavement to the north of the mirror about 2 metres from the mirror and sight to X and clamp the horizontal circle of the T2.
5. Place the pentaprism on the T2 taking care to not move the telescope in the horizontal plane.
6. Sight the mark X (with the pentaprism fitted) by moving the telescope in the vertical plane and rotating the pentaprism. When X is at the centre of the cross-hairs the line of sight is now in the vertical plane of the theodolite.
7. Set the azimuth of maximum dip of the inclined mirror (approx. 284º 45'). This is the azimuth of a line perpendicular to the strike-line of the mirror, where the strike-line is a horizontal line on the surface of the inclined mirror.
8. Set the zenith distance of the normal to the mirror (approx. 82º 40') making sure that the alidade bubble is correctly trimmed.
9. The cross-hairs of the theodolite should be in the centre of the reflected view of the pentaprism. Small adjustments can be to the inclination of the mirror by turning the nuts on the three brass screws locating the mirror in its housing.
10. Reverse the sequence of operations and check the azimuth to St Paul's.

IMAGES OF SHRINE MIRRORS

Bill Cameron placing plane mirror in outer aperture of Shrine

Inclined mirror mounted inside steel pillar on upper walkway of Shrine

View from inside roof of Shrine looking up at outer aperture

Sunbeam on Stone of Remembrance

View from inside roof of Shrine of sunbeam on the inner aperture.

SUN – NOVEMBER, 2010

UT d	h	R (h m s)	Dec (° ′)		E (h m s)	
1	0	2 40 42·8	S14 19·3	49	12 16 23·7	5
Mon.	6	41 42·0	14 24·2	48	16 24·2	4
	12	42 41·1	14 29·0	47	16 24·6	4
	18	43 40·2	14 33·7	48	16 25·0	3
2	0	2 44 39·4	S14 38·5	48	12 16 25·3	2
Tues.	6	45 38·5	14 43·3	47	16 25·5	2
	12	46 37·7	14 48·0	47	16 25·7	2
	18	47 36·8	14 52·7	48	16 25·9	1
3	0	2 48 35·9	S14 57·5	47	12 16 26·0	0
Wed.	6	49 35·1	15 02·2	46	16 26·0	0
	12	50 34·2	15 06·8	47	16 26·0	1
	18	51 33·3	15 11·5	47	16 25·9	1
4	0	2 52 32·5	S15 16·2	46	12 16 25·8	1
Thur.	6	53 31·6	15 20·8	46	16 25·7	2
	12	54 30·8	15 25·4	46	16 25·5	3
	18	55 29·9	15 30·0	46	16 25·2	3
5	0	2 56 29·0	S15 34·6	46	12 16 24·9	4
Fri.	6	57 28·2	15 39·2	45	16 24·5	4
	12	58 27·3	15 43·7	46	16 24·1	5
	18	2 59 26·4	15 48·3	45	16 23·6	5
6	0	3 00 25·6	S15 52·8	45	12 16 23·1	6
Sat.	6	01 24·7	15 57·3	45	16 22·5	6
	12	02 23·9	16 01·8	45	16 21·9	7
	18	03 23·0	16 06·3	44	16 21·2	7
7	0	3 04 22·1	S16 10·7	45	12 16 20·5	8
Sun.	6	05 21·3	16 15·2	44	16 19·7	9
	12	06 20·4	16 19·6	44	16 18·8	8
	18	07 19·6	16 24·0	44	16 18·0	10
8	0	3 08 18·7	S16 28·4	44	12 16 17·0	10
Mon.	6	09 17·8	16 32·8	43	16 16·0	10
	12	10 17·0	16 37·1	44	16 15·0	11
	18	11 16·1	16 41·5	43	16 13·9	12
	24	3 12 15·3	S16 45·8		12 16 12·7	

UT d	h	R (h m s)	Dec (° ′)		E (h m s)	
9	0	3 12 15·3	S16 45·8	43	12 16 12·7	12
Tues.	6	13 14·4	16 50·1	43	16 11·5	12
	12	14 13·5	16 54·4	42	16 10·3	14
	18	15 12·7	16 58·6	43	16 08·9	13
10	0	3 16 11·8	S17 02·9	42	12 16 07·6	14
Wed.	6	17 11·0	17 07·1	42	16 06·2	15
	12	18 10·1	17 11·3	42	16 04·7	15
	18	19 09·2	17 15·5	42	16 03·2	16
11	0	3 20 08·4	S17 19·7	41	12 16 01·6	16
Thur.	6	21 07·5	17 23·8	42	16 00·0	17
	12	22 06·7	17 28·0	41	15 58·3	17
	18	23 05·8	17 32·1	41	15 56·6	18
12	0	3 24 04·9	S17 36·2	41	12 15 54·8	18
Fri.	6	25 04·1	17 40·3	40	15 53·0	19
	12	26 03·2	17 44·3	41	15 51·1	19
	18	27 02·4	17 48·4	40	15 49·2	20
13	0	3 28 01·5	S17 52·4	40	12 15 47·2	20
Sat.	6	29 00·6	17 56·4	40	15 45·2	21
	12	29 59·8	18 00·4	39	15 43·1	22
	18	30 58·9	18 04·3	40	15 40·9	21
14	0	3 31 58·1	S18 08·3	39	12 15 38·8	23
Sun.	6	32 57·2	18 12·2	39	15 36·5	23
	12	33 56·3	18 16·1	39	15 34·2	23
	18	34 55·5	18 20·0	38	15 31·9	24
15	0	3 35 54·6	S18 23·8	39	12 15 29·5	25
Mon.	6	36 53·7	18 27·7	38	15 27·0	25
	12	37 52·9	18 31·5	38	15 24·5	25
	18	38 52·0	18 35·3	38	15 22·0	26
16	0	3 39 51·2	S18 39·1	38	12 15 19·4	27
Tues.	6	40 50·3	18 42·9	37	15 16·7	27
	12	41 49·4	18 46·6	37	15 14·0	28
	18	42 48·6	18 50·3	37	15 11·2	28
	24	3 43 47·7	S18 54·0		12 15 08·4	

Sun's SD 16′.2

SUNRISE

Date	South Latitude 60°	55°	50°	45°	40°	30°	20°	10°	0°	North Latitude 10°	20°	30°	40°	45°	50°	55°	60°
Nov.	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h
1	3·9	4·2	4·5	4·7	4·8	5·1	5·3	5·5	5·7	5·8	6·0	6·2	6·5	6·6	6·8	7·0	7·3
6	3·6	4·0	4·3	4·5	4·7	5·0	5·3	5·5	5·7	5·9	6·1	6·3	6·6	6·7	7·0	7·2	7·6
11	3·4	3·9	4·2	4·4	4·7	5·0	5·2	5·5	5·7	5·9	6·1	6·3	6·7	6·9	7·1	7·4	7·8
16	3·2	3·7	4·1	4·3	4·6	4·9	5·2	5·5	5·7	5·9	6·2	6·4	6·8	7·0	7·2	7·5	8·0
21	3·0	3·6	4·0	4·3	4·5	4·9	5·2	5·5	5·7	6·0	6·2	6·5	6·8	7·1	7·4	7·7	8·2
26	2·9	3·5	3·9	4·2	4·5	4·9	5·2	5·5	5·7	6·0	6·2	6·6	7·0	7·2	7·5	7·9	8·4
31	2·7	3·4	3·8	4·2	4·4	4·8	5·2	5·5	5·7	6·0	6·3	6·6	7·0	7·3	7·6	8·0	8·6

Moon's Phases: New Moon $6^d\ 04^h\ 52^m$ First Quarter $13^d\ 16^h\ 39^m$