

OT01 (40 points)

a) (10 points) Point the telescope at Saturn, then call your examiner for confirmation and marking after using the highest magnification available. If you are unable to point at the target, the examiner will do it for you, but you will get no points.

Solution	Point
Seen in the field of view using 10 mm eyepiece	10
Seen in the field of view using 25 mm eyepiece	5

b) (5 points) Write down your observing time and estimate the zenith distance z of Saturn.

Solution	Point
Write down the observing time	1
Check the results in the table below:	
$\pm 5^\circ$	4
If out of this range but within $\pm 10^\circ$	2

c) (11 points) Write down your observing time and estimate the acute angle of the rotation axis of Saturn relative to the horizon of the observing site.

Solution	Point
Write down the observing time	1
Check the results in the table below:	
$\pm 5^\circ$	10
If out of this range but within $\pm 10^\circ$	5

d) (14 points) The declination of Saturn is $+2^\circ$, assume that its diurnal circle is great circle, determine its hour angle HA at your observing time.

Solution	Point
Write down observing time	1
Check the results in the table below (available in two formats):	
$\pm 10m$ <i>Note: Adjust this value based on the previous answer of zenith distance.</i>	13
If out of this range but within $\pm 20m$	6

Observing Time		Solution					
		The solution values are based on the observing time					
h	m	1b) Zenith distance (°)	1c) Acute angle of rotation axis relative to the horizon (°)	1d) Hour angle			
				h	m	h	m
20	0	64	19	-4	11	19	49
	2	63			9		51
	7	62			4		56
	11	61	0		0		
	15	60	20	-3	56	20	4
	20	59			51		9
	24	58			47		13
	28	57			43		17
	33	56	21		38		22
	37	55			34		26
	42	54			29		31
	44				27		33
	46	53	22		25		35
	50	52			21		39
	55	51			16		44
	58				13		47
	59	50	23	12	48		
	21	4		49	-2	7	53
8		48		3		57	
9				2		58	
13		47	24	58		2	
17		46		54		6	
20				51		9	
22		45		25		49	11
26		44	45			15	
29			42			18	
31		43	26			40	20
35		42		36		24	
37				34		26	
40	41	27		31	29		
45	40		28	26	34		
49	39			22	38		

	51		29		20		40
	54	38			17		43
	58				13		47
	59	37			12		48
22	3		31	8		52	
	4	7			53		
	8	35		3		57	
	9			2		58	
	13	34	-1	58	22	2	
	14			57		3	
	18	33		53		7	
	19			52		8	
	23	32		48		12	
	27			44		16	
	28	31		43		17	
	31			40		20	
	34	30		37		23	
	35			36		24	
	39	29		32		28	
	42			29		31	
	44	28		27		33	
	45			26		34	
	49			22		38	
	50			21		39	
	52	27		19		41	
	54			17		43	
56	26	15		45			
57		14		46			
23		0		11		49	
		2		9		51	
	5	6	54				
	7	4	56				
	8	3	57				
	10	1	59				
	12	-0	59	23	1		
	14		57		3		
15	56		4				

0	16	22	53	0	55	0	5
	18		54		53		7
	21		55		50		10
	22		56		49		11
	24		57		47		13
	26		58		45		15
	28		59		43		17
	30	21	60		41		19
	32		61		39		21
	34		62		37		23
	35		63		36		24
	37		64		34		26
	39		65		32		28
	40	20	66		31		29
	42		67		29		31
	43		68		28		32
	45		69		26		34
	47		70		24		36
	48		71		23		37
	50		72		21		39
	51		73		20		40
	53	19	74		18		42
	54		75		17		43
	56		76		15		45
	57		77		14		46
	58		78		13		47
	0		79		11		49
	1		80		10		50
	3		81		8		52
	4		82		7		53
	6		83		5		55
	7		84		4		56
	8		85		3		57
	10		86		1		59
	11		87	0	0	0	0
	13		88		2		2
	14		89		3		3

	15		90		4		4
	17		89		6		6
	18		88		7		7
	19		87		8		8

OT02 (15 points)

Using the attached sky atlas page, point the telescope at Messier 29, then call your examiner for confirmation and marking after using the highest magnification available.

Solution	Point
Seen in the field of view using 10 mm eyepiece	15
Seen in the field of view using 25 mm eyepiece	10
Not seen in the field of view	0

OT03 (20 points)

Reverberation mapping (or echo mapping) is a technique used to estimate the mass of a black hole at the center of an Active Galactic Nucleus by observing the variations in light emitted from the system. In this setup, a repeating dot flash represents a sudden flare from the accretion disk, and a stationary concentric ring appearing after a while represents the light echoing through the gas region around the central black hole.

a) (5 points) Target Acquisition: Point your telescope toward the top floor of the Phenikaa Tower (the highest building on the Phenikaa campus), where the central dot and ring flashes will appear. Call your examiner for confirmation and marking. (If you cannot find the target, you may ask your examiner to point the telescope for you for 0 points in this part.)

Solution	Point
The ring and central dot flashes seen in the field of view	5
Not seen in the field of view	0

b) (10 points) Measure the time delay (τ) between the dot flash and the subsequent ring at least 3 times (up to 5 times). Record all individual readings, and calculate the mean time delay and its uncertainty.

Solution	Point
Recorded 3 to 5 individual measurements of τ . (Only 1–2 readings: 1 point)	5

$14.5 \text{ s} \leq \tau_{\text{mean}} \leq 15.5 \text{ s}$ and $\Delta\tau \leq 0.5 \text{ s}$ - If fails the condition above, but satisfies $14.0 \leq \tau_{\text{mean}} \leq 16.0 \text{ s}$ and $\Delta\tau \leq 1.0 \text{ s}$ awards 3 points. - If the mean (τ_{mean}) falls within a valid range above but the uncertainty ($\Delta\tau$) is missing, deduct half of the points earned.	5
Out of the above range	0

c) (5 points) Assume the gas orbiting the black hole with velocity of 3000 km s^{-1} and one measured second corresponding to one day. Calculate the black hole's mass M (in $M_{\odot}$).

Solution	Point
The ring radius: $R = c\tau = 3.88 \times 10^{14} \text{ m}$	2
The black hole's mass: $F_g = F_c \rightarrow \frac{GmM}{R^2} = \frac{m(\Delta V)^2}{R} \rightarrow M = \frac{R(\Delta V)^2}{G} \approx 2.6 \times 10^7 M_{\odot}$	3