13th Singapore Astronomy Olympiad

Data Analysis

14 March 2026

Instructions

1. The Data Analysis portion of this Olympiad is worth a total of **45 marks**.
2. When asked to do so, check that you have **9** printed pages.
3. Write your answers and workings clearly on the answer sheets provided.
4. Submit all used answer sheets.
5. Fill in these details on each side of your answer sheet:
   - Year of competition
   - Your participant code
   - The page number – which should be continuous from 1 to N
   - The question number
6. Cross out all workings or answers you do not wish to be evaluated.
7. If you require assistance (e.g. to visit the restroom, enquire about an ambiguity or possible errata, etc.), please get the attention of the invigilators.

Competition Rules and Regulation

1. Only the use of scientific calculators is permitted. No graphing or programmable calculators are allowed.
2. Disruptive behaviour, cheating, collusion to cheat or any integrity-related offences are grounds for immediate disqualification.
3. You may opt to retain the question paper and constants sheet for personal use. Return all unused answer sheets to the Organising Team.

The 13th Singapore Astronomy Olympiad is jointly organised by Astronomy.SG and the NTU Astronomical Society.

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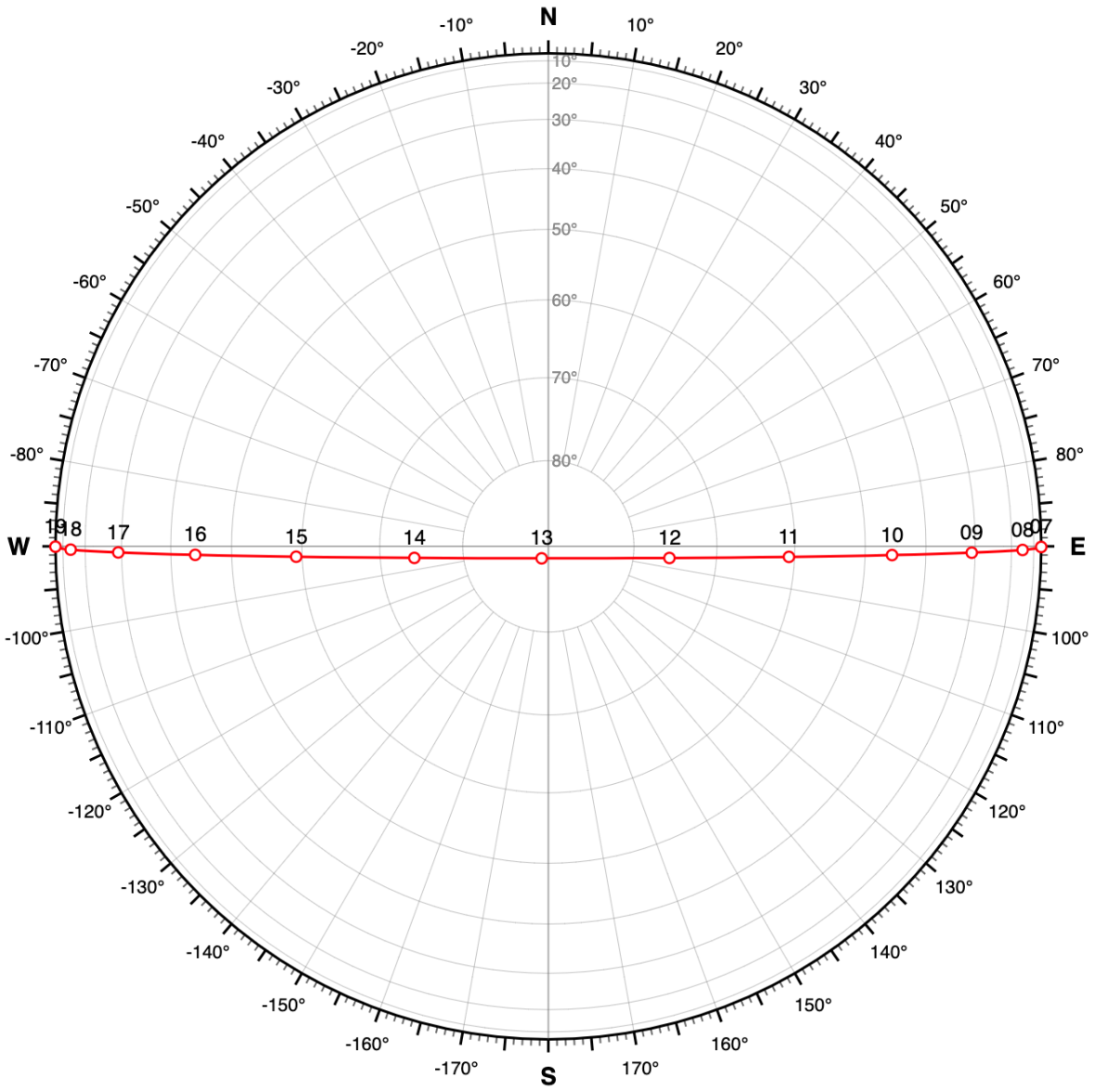
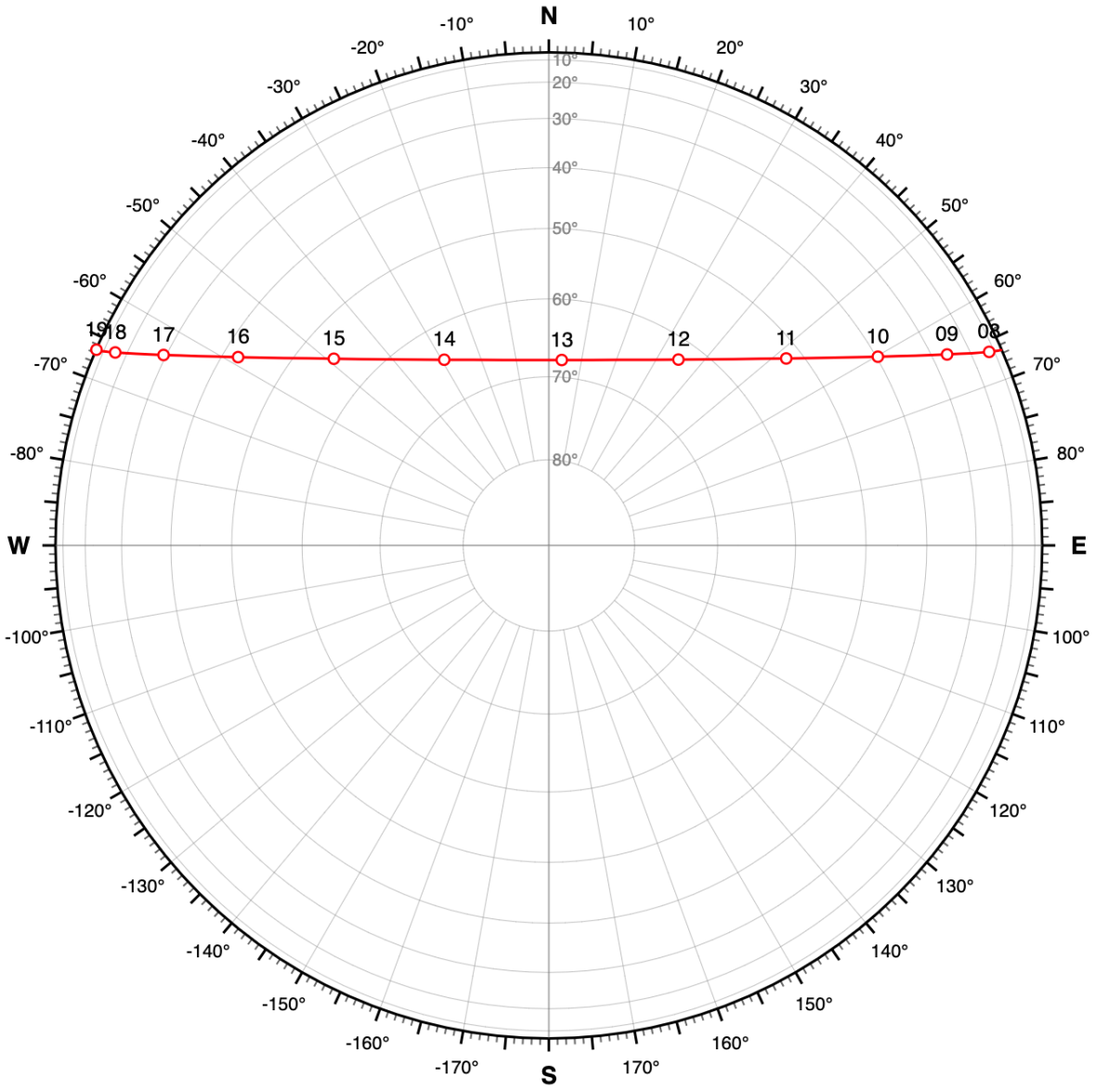
1 Path of the Sun [25]



[Diagram A]

(a) Diagram A shows a map of Singapore with the curved line representing the sun path for that day. Estimate the time which the sun rises and sets. [2m]

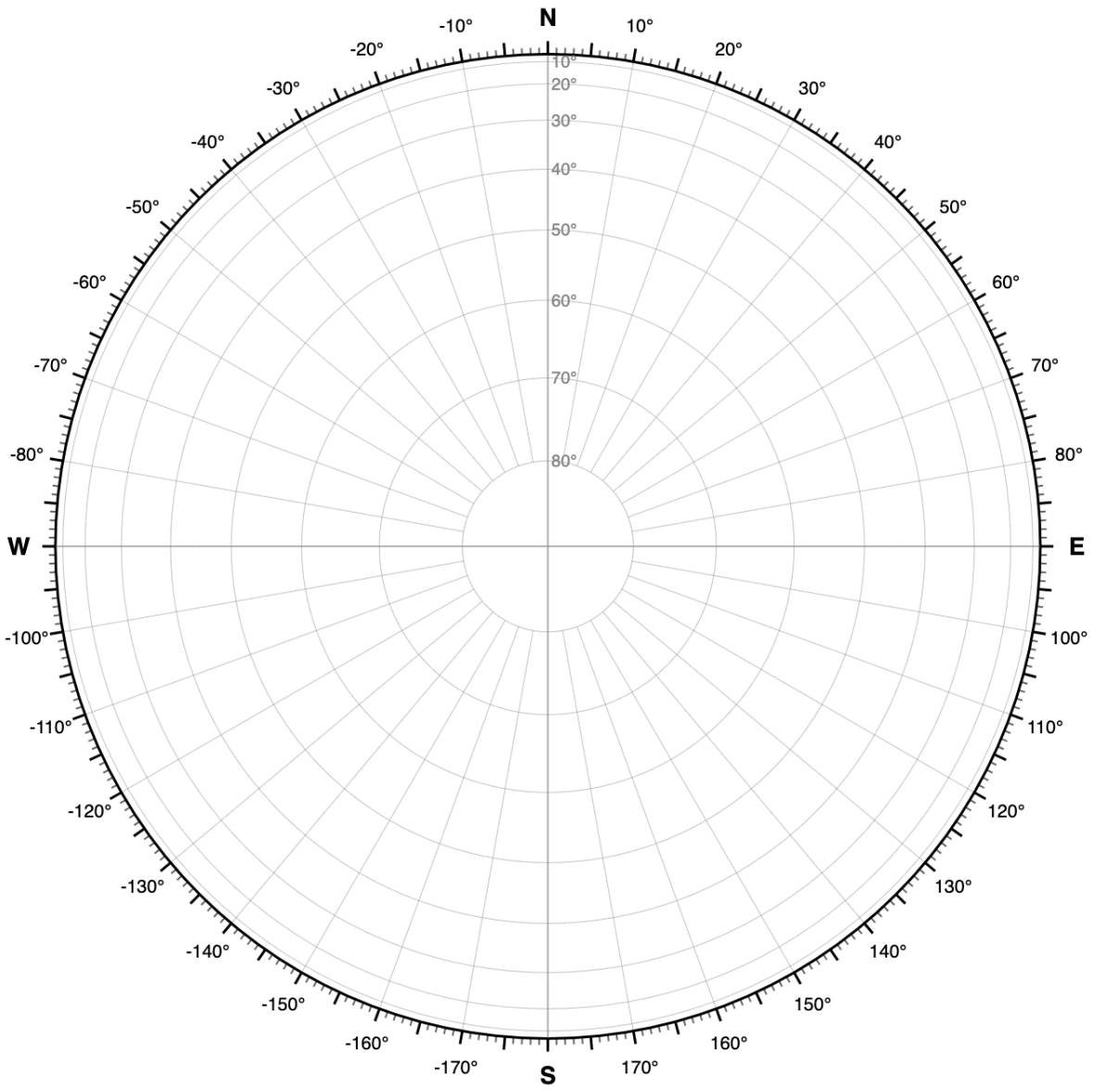


[Diagram B]

(bi) Diagram B shows the sun path on one of the solstices/equinoxes, draw and label the sun path on the 3 remaining solstices and equinoxes. [6m]

(bii) Explain what an analemma is and draw on Diagram A the 12pm analemma. [3m]

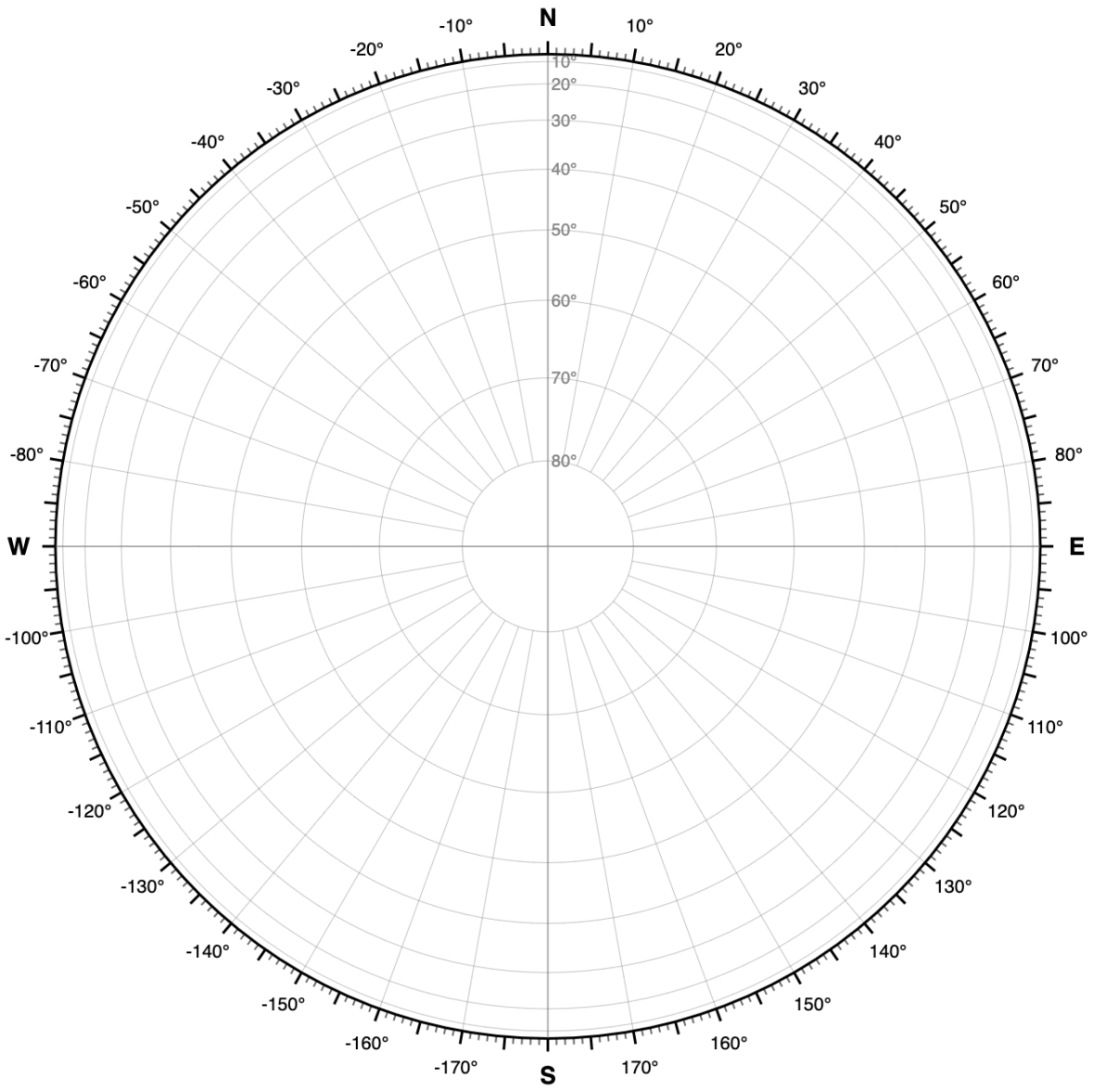
(biii) Hence, draw the 2pm analemma on Diagram A as well. [2m]



[Diagram C]

(ci) If the location was at New Zealand [47° S, 175° E] instead, draw on Diagram C the sun path for the solstices and equinoxes. [4m]

(cii) Hence, indicate the 12pm and 2pm analemma. [2m]



[Diagram D]

(di) If the location was at Iceland [65° N, 19° E] instead, draw on Diagram D the sun path for the solstices and equinoxes. [4m]

(dii) Hence, indicate the 12pm and 2pm analemma. [2m]

2 Far Far Away [20]

2.1 Candlelight

Table 2.1 lists the Right Ascension [RA], Declination [Dec] and Apparent Magnitude [Ma] of 40 RR Lyrae stars in the globular cluster Messier 3. RR Lyrae stars are standard candles with an absolute magnitude of approximately +0.75.

ID	RA	Dec	Ma	ID	RA	Dec	Ma
1	13:42:11.12	+28:20:33.8	15.591	21	13:42:37.78	+28:23:01.4	15.656
2	13:42:15.71	+28:21:41.8	15.545	22	13:42:25.92	+28:22:32.1	15.654
3	13:42:20.92	+28:28:10.0	15.496	23	13:42:02.84	+28:27:20.9	15.621
4	13:42:03.77	+28:24:42.8	15.607	24	13:42:00.31	+28:22:51.9	15.499
5	13:42:31.29	+28:22:20.7	15.592	25	13:42:02.08	+28:22:10.1	15.642
6	13:42:02.08	+28:23:41.6	15.686	26	13:41:58.05	+28:21:58.3	15.539
7	13:42:11.09	+28:24:10.2	15.688	27	13:42:03.17	+28:20:58.9	15.610
8	13:42:05.30	+28:22:18.8	15.634	28	13:42:09.63	+28:20:56.5	15.651
9	13:41:49.51	+28:19:13.3	15.630	29	13:42:06.58	+28:21:28.4	15.622
10	13:42:23.10	+28:25:00.6	15.615	30	13:42:08.72	+28:23:39.9	15.571
11	13:41:59.98	+28:19:11.8	15.580	31	13:42:13.97	+28:23:47.4	15.527
12	13:42:11.26	+28:20:17.0	15.557	32	13:42:12.39	+28:23:42.3	15.558
13	13:42:09.58	+28:20:24.4	15.673	33	13:42:16.83	+28:21:13.3	15.614
14	13:42:07.81	+28:20:01.1	15.506	34	13:42:21.71	+28:25:32.5	15.638
15	13:42:04.67	+28:18:08.5	15.597	35	13:42:03.44	+28:18:03.4	15.570
16	13:41:48.71	+28:21:08.0	15.676	36	13:42:24.55	+28:22:07.4	15.618
17	13:42:22.42	+28:15:22.7	15.620	37	13:41:53.56	+28:25:25.6	15.637
18	13:42:18.95	+28:17:47.3	15.673	38	13:41:56.04	+28:24:49.1	15.628
19	13:42:38.12	+28:18:37.8	15.679	39	13:41:52.97	+28:24:42.4	15.674
20	13:42:36.83	+28:18:11.8	15.611	40	13:41:50.93	+28:24:33.1	15.680

Table 2.1: M3 Star Parameters

(a) Find the distance to Messier 3 in light years. [4m]

2.2 Bundles of Stars

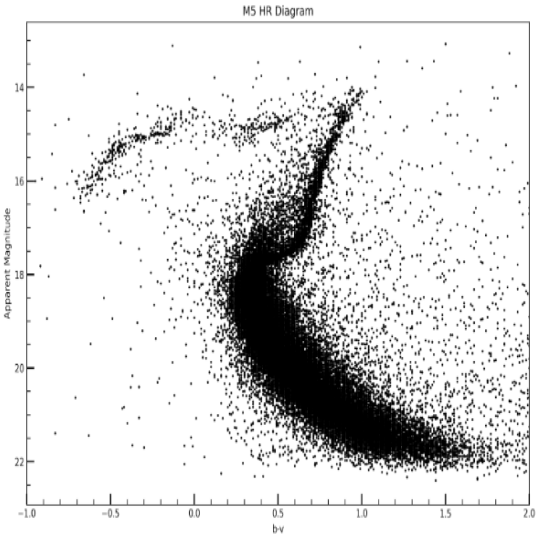


Figure X

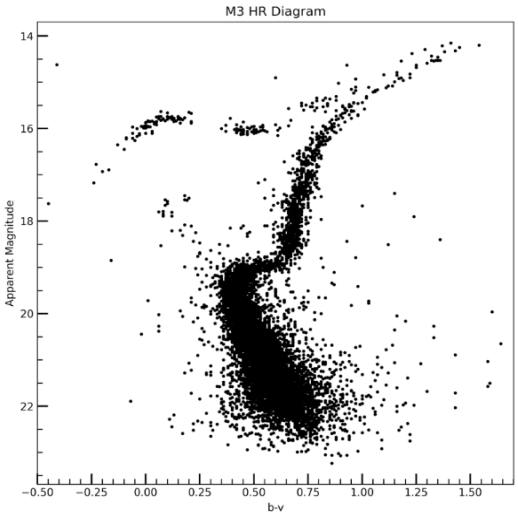


Figure Y

(b) Circle on Figure Y where these RR Lyrae stars will roughly be located in. [1m]

(c) Find the absolute magnitude of a star in M5 at the main sequence turn off point. [4m]

(d) Using your answer in c), find the distance to M5 in kly (kilo light years). [4m]

(e) By some unknown magic, Messier 5 is now located in a galaxy 721 Mly away. Find the recessional velocity of the galaxy. [1m]

(f) Hence, calculate the redshift z. [1m]

2.3 Turning Red

Table 2.3 lists the different lines in the Balmer series.

Line(s)	**Wavelength range [Å]**
H_{16}–H_{10}	3701–3801
H_9	3820.5–3852.5
H_8	3870.2–3910.2
$H\epsilon$	3941.2–4001.2
$H\delta$	4082.9–4122.9
$H\gamma$	4311.7–4371.7
$H\beta$	4812.7–4912.7
$H\alpha$	6512–6612

Table 2.3: Wavelength ranges of hydrogen spectral lines.

Figure 2.3 shows the absorption spectra of an A-Type star from exactly 400nm - 700nm. The 2 slightly extended thin black lines from the grid in Fig 2.3 represent 500nm and 600nm respectively. A-Type stars are characterised by their distinct Hydrogen absorption lines.

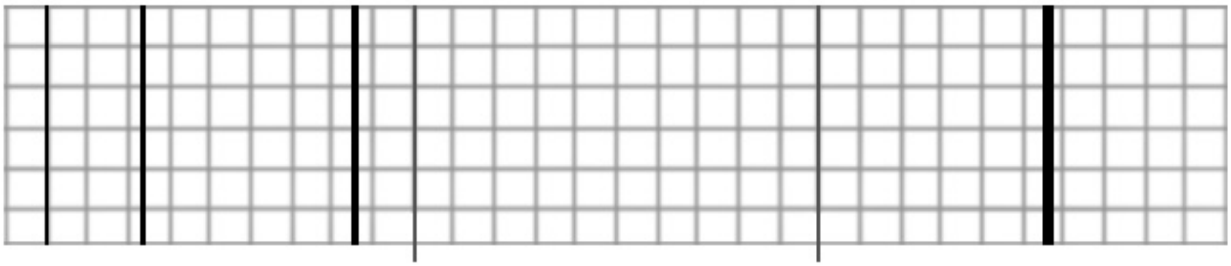


Figure 2.3: Spectra of a Type A star from 400 nm - 700 nm

(g) If M5 was indeed at this distance, sketch the observed spectra of an A-Type star within M5 in Figure 2.4 below. [5m]

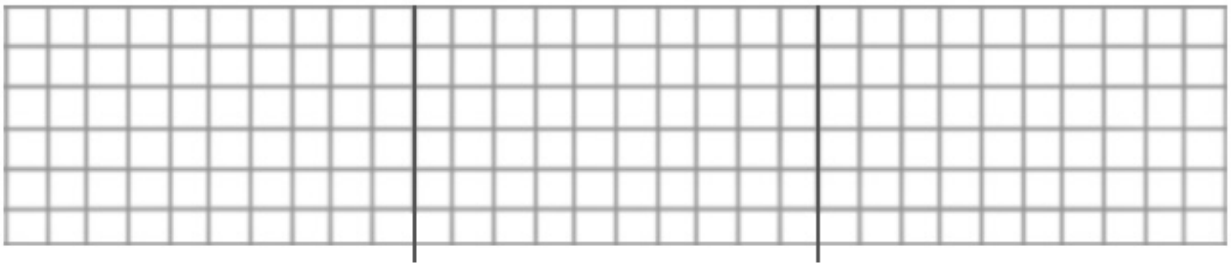


Figure 2.4: Blank spectra from 400nm - 700nm