AstroChallenge 2007

NTU-NUS ASTROCHALLENGE

Round 2: Data Response (Senior Category)

There are a total of 6 pages in this question set including this page.

Time allowed: 90 minutes.

Instructions to competitors:

1) Do not turn over this question booklet until you are told to do so.
2) You may attempt to answer as many parts of the question as you can, not necessarily in the order they appear.
3) Communication between members of the same team is allowed. Any other form of unauthorized communication or reference to material in verbal, written, print, electronic or any other forms may subject the team to penalties including possible disqualification.
4) The use of electronic calculators and rulers is allowed and expected.
5) The number of marks allocated to each part is indicated in square brackets after the question.
6) Write your answers on a separate sheet of A4 paper and attach the question booklet IN FRONT of your answer sheets. Failure to do so will be deemed as an attempt to cheat.
7)

Round 2: Data Response (Senior Category)

TEAM NAME: ____

For markers' use only

a	b	c	d	e	f	g	h	i	j
20	**70**	**50**	**50**	**50**	**50**	**80**	**100**	**40**	**30**

k	l	m	n	o	p				Total
30	**30**	**40**	**30**	**160**	**20**				**850**

(a) How bright an object appears to the eye depends on how much light enters the eye, which is again dependent on the detected flux based on the sensitivity of the eye and the area of the eye.

The magnitude scale that astronomers use is defined by

$$m = C - p \lg F$$

where m is the magnitude, C is a constant that depends on the sensitivity of the instrument and p is a constant whose value can be calculated theoretically.

Before this formula may be used to obtain the unknown magnitude of an object by measuring its flux, at least one reference object with a known predefined magnitude must be identified and its flux must be measured. Explain why this is so. [20]

(b) The table below shows a list of reference objects with known magnitudes and the corresponding flux as measured by an instrument.

Object	Apparent magnitude/mag	Measured flux/(10^{-8}W/m²)
Sirius	-1.47	11.169
Canopus	-0.72	5.5976
Arcturus	-0.04	2.9923
Alpha Cen A	-0.01	2.9107
Vega	0.03	2.8054
Rigel	0.12	2.5823
Procyon	0.34	2.1086
Achernar	0.50	1.8197
Betelgeuse	0.58	1.6904
Hadar (Agena)	0.60	1.6597

Plot a suitable graph to obtain the values of C and of p for this instrument. [50]

From your graph, deduce the difference in flux corresponding to a difference of 5 magnitudes. [20]

(c) Theoretically, a difference in 5 magnitudes corresponds to a ratio of exactly 100 times in the flux. Find the theoretical value of p correct to 4 significant figures. Show your working clearly. [50]

(d) The absolute magnitude of an object, M, is defined by $M = C - p \lg F_{10}$ where F_{10} denotes the flux measured at a distance of 10 parsecs from the object. 1 parsec is defined as the distance to an imaginary object that subtends an angle of parallax of 1” [1 arc second, equals to (1/3600)°]. Using first principles, express 1 parsec in terms of AU, where the distance from the sun to the earth is 1 AU. You may invoke any valid approximations involving small angles. [50]

(e) The inverse square law states that the flux varies inversely with the square of the distance *r*. Using this relation as well as the equations $M = C - p\lg F_{10}$, $m = C - p\lg F$ and assuming p = 2.5, show that $M = 5 - 5\lg r + m$ for *r* in parsecs. [50]

(f) Hence, explain why knowledge of the intrinsic brightness of an astronomical object (i.e. how much light the object actually emits) is of such paramount importance. [50]

(g) An ordinary filament light bulb converts 10% of its power into light and the remainder into heat. Also assuming p = 2.5 and that all the light that reaches the instrument is registered by the instrument, find the absolute magnitude of a 100 W filament light bulb. Hint: you may use your answer in (d). [80]

(h) For any astronomical object, the amount of light energy F_λ emitted at different wavelengths λ is dependent on its temperature T, according to Planck's Radiation Law for black bodies

$$F_\lambda = \frac{2\pi hc^2}{\lambda^5}[\exp(hc/\lambda kT) - 1]^{-1}$$

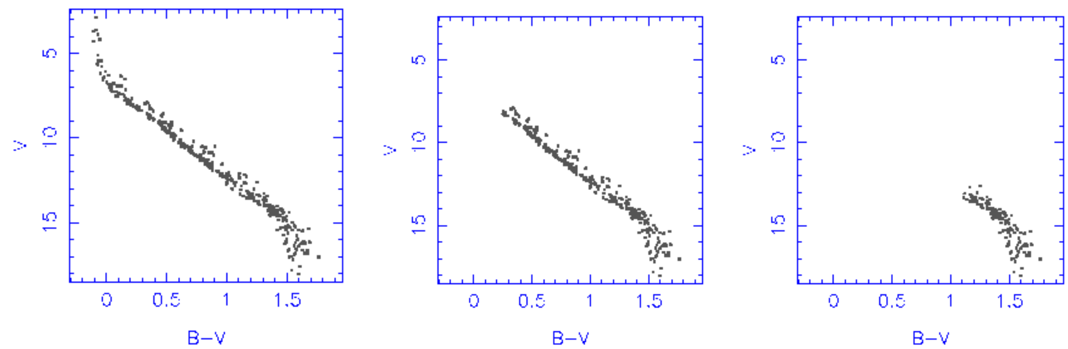
where $h = 6.63 \times 10^{-34}$ J s, $c = 3.00 \times 10^{8}$ m s^{-1} and
$k = 1.3806503 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}

By differentiating F_λ with respect to λ, find the relationship between λ and T when F_λ is a maximum. Evaluate the constant term to 4 significant figures. [100]

(i) Because of the difference in the brightness at different wavelengths, we can find the difference in magnitudes of the light at different wavelengths and compare them for a sense of the colour and the temperature of a body. Denote *B* as the magnitude over the blue region of the wavelength and V as the magnitude over the yellow region of the wavelength, suggest, with reference to the formula relating magnitude to flux, whether the colour index *B-V* is likely to be positive or negative for (I) a red star and (II) a blue star. [40]

(j) In determining the colour index *B-V*, should we use the apparent or absolute magnitude over the said wavelengths? Give a reason for your choice. [30]

(k) The following H-R diagrams are plots of *m* on the vertical axis and *B-V* on the horizontal axis for some star clusters, with the diagram on the left showing the youngest cluster and that on the right showing the oldest cluster. Only stars on the main sequence are shown. Describe the pattern observed. [30]



(l) Discuss why in the H-R diagrams in (k), the apparent magnitude of the individual stars *m* is used rather than the absolute magnitude *M*. [30]

(m) For stars on the main sequence, do red stars or blue stars have longer life spans? Justify your answer with evidence from the above, as well as give an explanation why this could be so. [40]

(n) For a galaxy, the colour index will be the collective colour indices of the stars that make up a galaxy. It is noticed that for spiral galaxies, the core is 'redder' than the spiral arms, even after the effect of dust near the core is taken into account. What inferences can you draw about the comparison between the stars in these regions? Justify your answers. [30]

(o) The following table shows the physical properties of 20 galaxies.

Name	Type code, T	Axis ratio, r	(B-V)/mag	Fractional effective aperture
A	4.0	9.49	0.647	0.675
B	5.8	8.93	0.559	0.524
C	6.4	2.93	0.529	0.977
D	1.3	5.80	0.783	0.034
E	7.9	2.45	0.455	0.240
F	2.6	1.69	0.721	0.081
G	6.8	4.75	0.510	0.031
H	8.1	5.45	0.443	0.923
I	8.1	8.24	0.445	0.632
J	8.9	2.54	0.405	0.142
K	5.4	10.04	0.581	0.100
L	7.3	7.36	0.484	0.462
M	8.8	10.55	0.408	0.450
N	2.4	3.83	0.731	0.064
O	3.8	3.63	0.666	0.464
P	7.5	4.01	0.476	0.029
Q	5.5	9.23	0.572	0.292
R	1.5	4.93	0.776	0.508
S	6.0	2.26	0.551	0.018
T	6.3	3.60	0.535	0.996

For the data given above, describe any patterns observed. For any relationship observed, plot a graph of that relationship, find the possible equation that connects the related quantities, and comment on how reliable your equation is in predicting an unknown quantity. [160]

(p) For spiral galaxies, the type code *T* is a number between 1 and 9 assigned by astronomers based on how tightly the spiral arms are wound, with smaller numbers being assigned to galaxies with tight arms. In another classification scheme, spiral galaxies are denoted with the letter S and galaxies with tight arms are assigned Sa and those with very loose arms are assigned Sd. The Milky Way galaxy is assigned Sbc under this scheme. Predict its type code. [20]

The End