Set - Senior

National Round - 2020

Total Marks:

BDOAA
BANGLADESH OLYMPIAD ON ASTRONOMY AND ASTROPHYSICS 2020

Time: 3 Hour

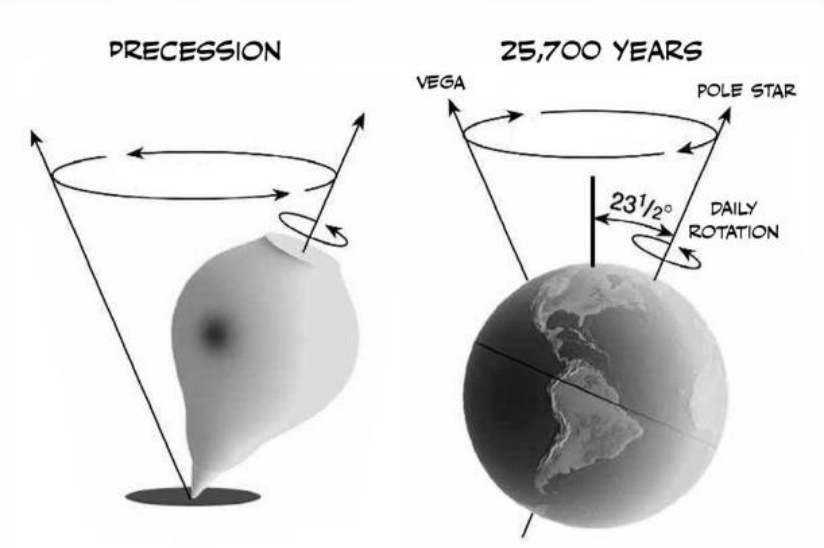
Name:
Class:
Institution:
Email:
Phone Number:

- The candidate must write his/her personal information and registration number on the answer script.
- You will write your answer in the space provided. If you need more space, use asterisk (*) and Question No. in extra paper from the exam invigilator.
- For all questions, the process involved in arriving at the solution is more important than the answer itself. Valid assumptions / approximations are perfectly acceptable. Please write your method clearly, explicitly stating all reasoning.
- Be sure to calculate the final answer in the appropriate units asked in the question.
- Non-programmable scientific calculators are allowed.
- The mark distribution is shown in the [ ] at the right corner for every question.

Table of Constants and Formulas:

- Luminosity of Sun, $\mathbf{L_\odot} \approx 3.826\ 10^{26}$ W
- Radius of the Sun, $\mathbf{R_\odot = 7}\ \times 10^{8}$ m
- Radius of the Earth, $\mathbf{R_\oplus} \approx 6.371 \times 10^{6}$ m
- Stefan-Boltzmann Constant , $\boldsymbol{\sigma} = 5.67 \times 10^{-8}$ W/m^2
- Mass of the Sun, $\mathbf{M_\odot} = 2\times 10^{30}$ Kg
- Gravitational Constant, $\mathbf{G} \approx 6.674\times 10^{-11}$ Nm^2/kg^{-2}
- Astronomical Unit, $\mathbf{AU} = 1.496 \times 10^{11}$ m
- Distance Earth-Moon = 3.8440×10^{8} m

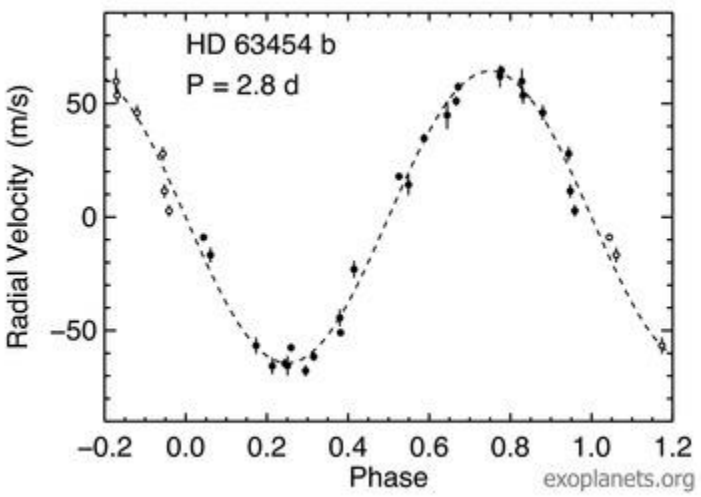
1. Astronomical Time!



a) What is the sidereal time at midnight (standard time) tonight (4th January, 2020)? Give your answer in hours to an accuracy of two significant figures. [2]
b) Using the fact that the period of precession of Earth's rotational axis is about 25.700 years, estimate the rate at which the vernal equinox moves along the ecliptic [2]
c) By definition, the tropical year is measured between successive passes through the vernal equinox. Find the difference (longer/shorter) between Sidereal year and Tropical year. [3]

2. Planet around HD 63454

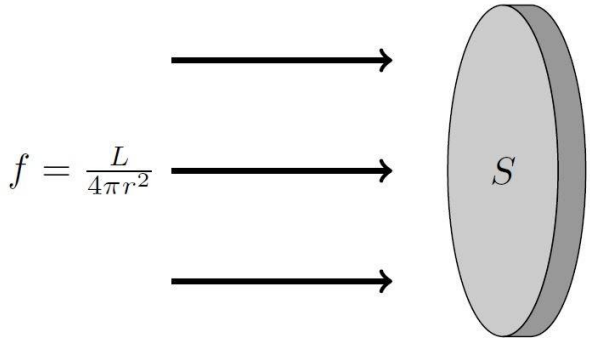
HD 63454 is a $0.7M_{\odot}$ star known to have an extrasolar planet orbiting in a circular orbit with an orbital period of 2.82 days. The distance of this system is 35.8 pc and the measured radial velocity curve for HD 63454 is shown in the figure
Use the information to determine:



a. The minimum mass of the planet [3]
b. The radii of the stars and planet's orbit [3]
c. The maximum astrometric shift of the star due to its orbital motion, expressed in arcseconds [3]

3. Sun Rays and Solar Bodies

Two identical thin, flat, near-Earth asteroids initially orbit the Sun in the same orbit at r = 1.0 AU. Their two sides are like the faces of Iapetus: one face has albedo, A_b = 0.05 and emissivity, ε = 1 and the other face has albedo, A_b = 0.5 and emissivity, ε = 1 that are the same at all wavelengths. Each has a mass of $10^{10}\ kg$. Suppose that their flat sides have area 1 km^2 and that one asteroid has its dark side facing the Sun while the other has its shiny side toward the Sun.



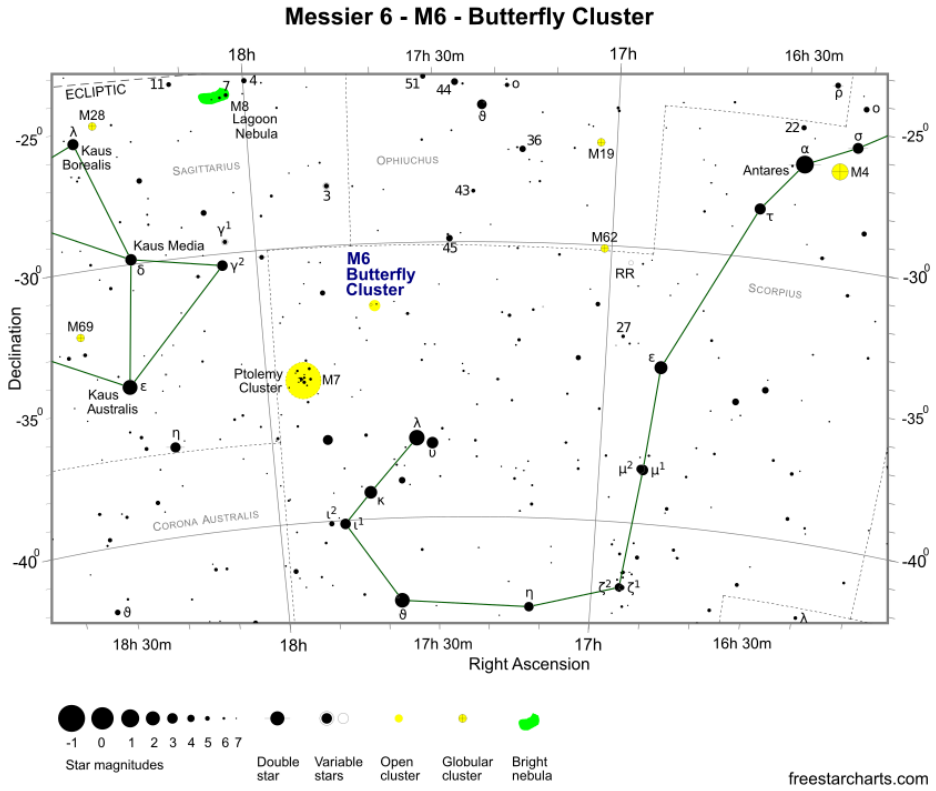
a) What is the temperature of each asteroid? For simplicity, ignore absorption and emission by the thin edges of the asteroid and assume it is uniform in temperature. [2]

b) Derive a formula for the magnitude of the radiation force,F_{rad}, on such an asteroid. [3]

c) Calculate the time in years that it would take for each of the two asteroids to drift inward by the Earth-Moon distance, **Δr** = 3.844 ×10^{10} cm, if they rotate synchronously (each always shows the same face to the Sun). [4]

d) Suppose that we have a planet with no atmosphere in a circular orbit of 1 AU from a star just like the Sun. The planet has a uniform albedo and rotates with a period equal to its orbital period so that it always shows the same face to the Sun. Neglecting the conduction of heat, what is the distribution of the temperature on its sunlit side? [5]

4. Planning Observations Using Skymaps



Messier 6 - M6 - The Butterfly Cluster is open cluster that can be seen in naked eye in clear skies in Bangladesh. Its celestial coordinates are DEC = −32° 13′ and RA = 17^{h} 40.1^{m}.

a) What is the best time of the year to observe this cluster in Bangladesh? [2]
b) It is not practical to observe targets at altitudes a < 30°. What is the maximum latitude in northern hemisphere from which M6 can still be studied? [3]
c) Calculate the galactic coordinates of M6. Sketch the galactic coordinate system, indicating the location of galactic poles, Galactic center and M4. Based on your result, does M6 lies on the Galactic plane? [4]
d) Draw celestial sphere for Bangladesh depicting galactic center, North Pole, and M4. [2]

5. Sirius

Sirius A (the brighter component in Sirius binary Star system) is one of the closest stellar neighbors and brightest star as seen from the Earth. Its surface temperature is close to 9910K and it is 23.5 luminous than our star. The parallax of Sirius has been measured to be 0.38″. Find the following properties of Sirius A:

a) Radius in Solar Units. [2]
b) Absolute bolometric magnitude (Hint: Use the fact that M_{bol} = 4.76 for the Sun.) [3]
c) Peak wavelength. Is your result consistent with the fact that Sirius appears to be blue/white in color? [2]
d) Let's assume that the sensivity functions of standard filters can be approximated as step functions. Let's also assume that the filters are narrow that specific flux from a star does not vary significantly over the width of a filter. Compute the apparent magnitude of Sirius in V band. Use the fact that star with $m_V = 0.0$ has specific flux $F_\lambda = 3.8 \times 10^{-12}$ Js^{-1} m^{-2} A^{-1} near the peak of the V-band. [3]
e) Compute the absolute magnitude of Sirius in V-band. [3]

Practical Section

Data Analysis:

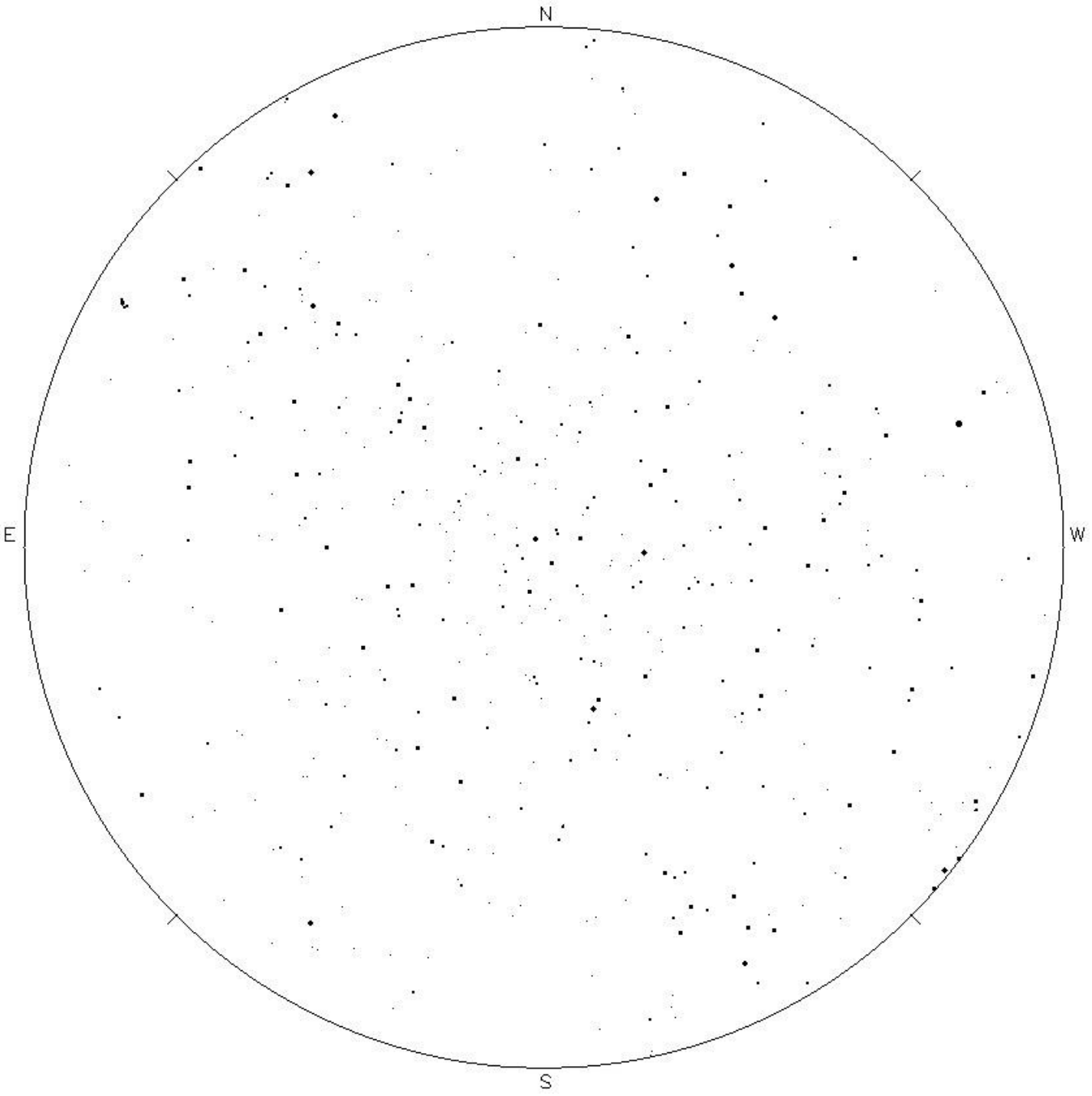
Hubble's Law

Galaxy Name	Distance (Mpc)	Radial Velocity(km/s)
DDO 069, Leo A	0.783	-19
DDO 216, Peg DIG	0.964	-20
GR8, UGC 08091	1.95	183
NGC 5128	3.42	398
M31, NGC 0224	0.809	-121
IC 4182	4.39	362
M101, NGC 5457	6.85	360
M106, NGC 4258	8.43	510
M33, NGC 0598	0.847	-46
M66, NGC 3627	12.6	643
M81, NGC 3031	3.63	69
M83, NGC 5236	4.61	384
M95, NGC 3351	10.5	677
M96, NGC 3368	11.7	798
NGC 0300	1.98	98
NGC 0925	9.29	665
NGC 1637	12	639
NGC 2090	12.5	746
NGC 2403	3.06	226
NGC 2541	12.6	586

NGC 2841	14.1	674
NGC 3198	14.5	684
NGC 3319	14.1	755
NGC 3621	7.24	526
NGC 5253	4.07	271
NGC 6822	0.459	44
NGC 7331	15.1	1035
NGC 3109	1.3	194

a. Plot the above data points in a graph. Label the axis and use at least 80% area of your graph paper. Keep velocity in y-axis and distance in x-axis.
b. For some graphs, we assume that the best fit line will must go through the origin (0,0) of the graph. Does this assumption hold for this graph? Explain your reasoning.
c. Why some galaxies have negative velocity? What insight we get from that?
d. Draw the best fit line using the data points. Estimate the value of the slope and the intercept?
e. Estimate the error of the slope using your line. Don't forget to include units in your answer.
f. What can you say about Hubble's constant from the graph? And what insights we get regarding our understanding of universe from this?

Star Charts



a. Label the Zenith (Z), North Pole Star (P) and First point of Aries (γ) on the map. [3]

b. Draw any 5 constellations on the map and name the alpha stars in each constellation. [2.5]
c. Draw the Equator (Eq) and the Ecliptic (Ec) on the map and label them. [Within 5° degrees accuracy] [2]
d. Label the stars, “Dubhe”, “Gemma” and “Mirphak” on the map with their respective names. [3]
e. Identify and label the radiant point of Perseid Meteor Shower on the map as “R”. [2]
f. Identify the brightest star on the map with a circle and write its name beside it.
g. If the Sun is near Regulus (Constellation Leo), then estimate the month when this skymap was created. [3]