4^{th} Bangladesh Olympiad on Astronomy and Astrophysics

Sample Problems 2021

Note: These question are above the usual standard for first round exam of BDOAA, so don't get frustrated. This questions are set to give you an idea on what to expect.

1 Meteor Struck

It is said that it is rare to be hit by a meteorite on the Earth. Let us try to investigate how rare it is on the Moon. The radius of moon, $R_{\leftmoon} = 1,737.1$ km.

a. Assuming that it is a perfect sphere, calculate its surface area. About 2700 kg of cosmic material falls onto the Moon daily. Most of it consists of microscopic particles and dust. Assume that all of them had the size of air rifle bullets with mass 0.500 g and that they cover the surface of the Moon homogeneously.

b. Calculate the surface area on which (on average) exactly one bullet galls per day. Round the result to 3 significant digits.

c. The Apollo 11 mission explored about $750\,m^2$ of the Moon's surface. How many days on average should we wait until a meteorite of the size of this bullet falls onto this area?.

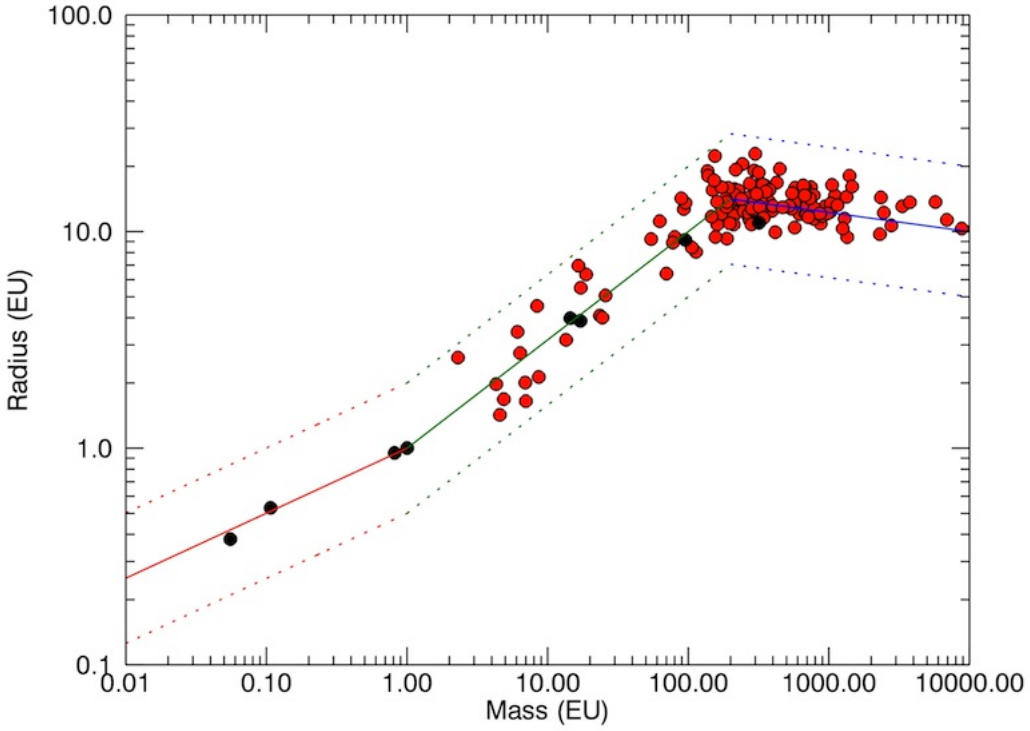
d. What are the odds that such a body will hit an astronaut during a day on the Moon outside the landing Module.

Solution Prerequisite Knowledge

- Celestial Mechanics (Gravitation),
- Significant Digits and Rounding estimates,
- Geometry of Objects,
- Mass Flux.

2 Exoplanetary Scientist

Fahim worked on exoplanets during 2020 where he was curious about the evolution of the exoplanetary atmosphere. From his research he found this graph—



Empirical mass-radius relation for exoplanets. The dotted lines show two and half times the predicted value, all fall within this maximum error boundary. The data is from confirmed exoplanets with mass and radius. EU = Earth units.

a. From the graph predict 3 separate equations for mass radius relation of these data points.

b. If the radius of the Earth is 6,371 km calculate the mass of the Earth, and the kinetic energy and pressure involved when the Earth gets hit by a meteorite of mass 0.001 EU, density $3400\,\mathrm{kg/m^3}$.

Solution Prerequisite Knowledge

- Linearization of Graphs,
- Different types of Graph– log-log,
- Work, Energy, and Power
- Exoplanet Structure Basic Idea.

3 Celestial Mechanics

A minor planet revolves around the Sun. This minor planet is observed in the same position every two years, under constant conditions. Throughout these two years, the maximum and minimum difference in magnitude observed from Earth is 8. Consider the minor planet to be smooth, spherical, with constant surface albedo and that it can be observed during the day as well. You may take Earth's orbit to be circular.

a. How many revolutions per 2 years does the minor planet make if its orbit never comes inside Earth's orbit?

b. Explain why the minor planet cannot have an orbital period of 1 year if the minor planet's orbit is elliptical or if the minor planet's orbit is circular.

c. Using Kepler's 3rd law, deduce the minor planet's semi-major axis, a.

d. Sketch a diagram showing the relative positions of the Sun, Earth and the minor planet when the minor planet is at maximum and minimum magnitude. Label these points (1) and (2) respectively.

e. Find the minor planet's minimum eccentricity e. The observed magnitude m is given by

$$m = H + 2.5\, log\left(\frac{d^2 r^2}{p(\chi)}\right),\ 0 \leq \chi \leq 1.$$

where d is Sun-object distance, r is Earth-object distance, $p(\chi)$ is the phase integral which represents how much light is reflected that depends on the phase angle. H is the apparent magnitude of a an object when viewed at exactly 1 AU with a full phase integral. Note: If you are unable to derive the semi-major axis in part c., you may use the value 2.0 AU for this part.

Solution Prerequisite Knowledge

- Flux, Magnitude, and Albedo for Blackbody,
- Orbits (Elliptical, parabolic, and circular),
- Kepler's Laws.

4 Astronomy on Mars

Elon Musk has sent Neha on mars to navigate Martian sky. Neha noticed that the Martian north celestial pole is located in Cygnus and has coordinates– **Declination**, $\delta_M = +52°53.0'$ and **Right Ascension**, $\alpha_M = 21^h10^m42^s$.

a. Mark the location of these coordinates on the star map provided. Consider this map as similar to Declination Latitude and R.A. Longitude.

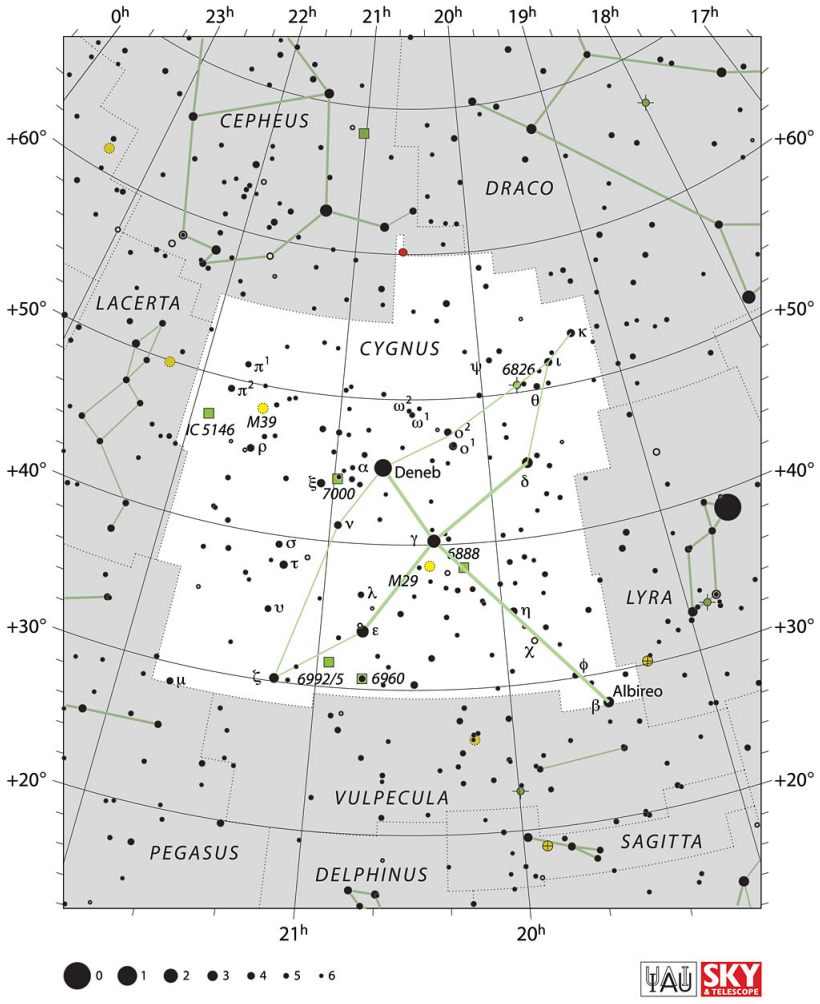


Image taken from:`https://www.iau.org/public/images/detail/cyg/`

b. The constellation Cygnus can be viewed on the North-western side of our Rajshahi Sky. Consider that Cygnus never sets below the horizon for a certain location on Mars' surface and it is also viewed from the North. Find the latitude, ϕ_M of that location on Mars surface

Solution Prerequisite Knowledge

- Constellations and Stars,
- Astronomical Spherical Coordinate System,
- Geometry of Celestial Sphere.