NUS-NTU AstroChallenge Syllabus

This syllabus has been compiled as a preparation guide for AstroChallenge. It is the quiz-masters' utmost wish that the focus of the paper be shifted away from trivia-based learning towards a more conceptual approach focused on understanding and application. By encouraging such an approach, AstroChallenge aims to promote a scientific and logic based reasoning process that students will not only be able to apply to Astronomy, but also to the major sciences taught in the school's curriculum. The Syllabus will be uploaded on the website at www.astrochallenge.org.

This syllabus can and will be subjected to minor changes from time to time.

Basic Celestial Mechanics

Participants will be required to have a good grasp of geometry and basic trigonometry in the context of astronomy. They are also encouraged to have a good understanding of the physics behind celestial mechanics.

1. Account for the motion of celestial bodies
2. Understand the concept of the celestial sphere, coordinate systems, orbits of planets, and terminology including conjunction, opposition, elongation, aphelion, perihelion
3. Be familiar with Earth's orbital motion; the difference between solar and sidereal day, tropical and sidereal year; and the analemma
4. Relate Earth's axial tilt and precession with basic astronomical timekeeping
5. Be familiar with the basis of lunar and solar calendars
6. Understand the occurrence of transits, lunar and solar eclipses

History of Astronomy

Participants are expected to understand the significance of astronomical discoveries in the context of their respective topics. It is also highly encouraged that participants learn how competing theories in the past are disproved or reinforced. Participants will not be specifically tested on the names of astronomers or physicists and their work.

The Solar System and extrasolar systems.

Participants are not required to know the specific names of asteroids, moons, or Kuiper-belt objects. Memorisation of physical data as well as specific names of geographical features pertaining to the Sun and planets is not required. Geology of Earth will not be covered.

1. Understand the formation of planets, namely the nebular hypothesis, protoplanetary disks, accretion mechanisms, planetary migrations and the Nice Model
2. Recall distinct features and geology of Solar System planets and their respective major natural satellites along with theories regarding their formation and/or mechanism
3. Compare and contrast various theories of the Moon's formation
4. Account for the formation, decay and composition of planetary rings
5. Be familiar with Roche limit and resonance orbits in relation to orbital stability, rings and asteroid belt formation
6. Describe the location of the Asteroid belt, Trojan Asteroids, Kuiper Belt, Oort Cloud and the properties of its members as well as theories of formation
7. Know Kepler's Laws of Planetary Motion
8. Be familiar with associated theories related to the formation of comets
9. Be aware of hypothetical theories of planets and other objects - Vulcan, Nemesis, Planet X, as well as tests of these theories.
10. Understand the methods of detecting and studying exoplanets

The Sun, the Stars and Stellar Evolution

Participants are not required to memorise specific names of stars or star clusters nor will they be required to memorise specific examples of deep space objects. A good understanding of thermodynamics and the ideal gas law is encouraged here.

1. Recall physical properties of the Sun and the solar interior
2. Understand the solar cycle, sunspots, solar flares and coronal mass ejections
3. Understand the solar neutrino problem and its resolution
4. Understand the process of stellar nucleosynthesis and dominant pathways
5. Understand the mechanism of the proton-proton chain, CNO cycle and the triple-alpha process

6. Understand the concepts of magnitude, luminosity and brightness in relation to celestial objects
7. Be familiar with blackbody radiation in relation to physical properties of stars, including temperature, mass, and radius
8. Know the significance behind the Hertzsprung-Russell Diagram as well as how it is used and constructed in practice.
9. Describe interstellar matter and different types of nebulae
10. Account for the extinction and reddening of light
11. Know the mechanism of stellar birth and evolution
12. Know the formation of Star Clusters, and illustrate Open clusters and Globular Clusters on HR diagrams
13. Understand the concept of metallicity, with relation to stellar generations (Pop I, Pop II and Pop III stars)
14. Recall the various types of variable stars and their mechanism of pulsation, most notably Cepheids
15. Know the classification of binary stars and their light curves
16. Understand the processes occurring in mass transfer binaries and how the Roche limit and Roche Lobe applies.
17. Account for stellar explosions: Planetary nebulae and Supernovae (Ia and II)
18. Be familiar with accretion disk mechanisms
19. Describe the mechanism and evolution of pulsars
20. Account for Gamma-ray bursts and X-ray bursts
21. Describe the structure of black holes
22. Recall the no-hair theorem coined by John Wheeler
23. Have a brief understanding of the theory of Hawking Radiation and Hawking temperature

Relativity

Questions pertaining to relativity will only be asked in relation to an astronomical setting. General Relativity will only be tested in a qualitative sense while adequate formulas will be provided for Special Relativity

1. Recall the postulates of General Relativity and Special Relativity
2. Understand the consequences of General Relativity and Special Relativity, and how they differ from classical mechanics.
3. Perform calculations using the Lorentz factor and transformations

Observational Techniques in Astronomy and Empirical Applications

Participants are not required to memorise specific names, dates nor destinations of manned or unmanned spacecraft. They should understand the use of the following:

1. Understand the construction of the cosmic distance ladder scale – derivation, theoretical foundations as well as common standard candles (Type Ia, Cepheids and RR Lyrae stars)
2. Know how to find distances to stars and galaxies through techniques such as spectroscopic parallax, main sequence fitting and other given distance relations.
3. Understand how to measure the Astronomical Unit and distances within the Solar system.
4. Adaptive and corrective optics
5. Radio telescopes and the use of interferometry
6. Advanced telescopes operating in the entire electromagnetic spectrum
7. Understand the reasons for the global distribution of large professional telescopes

Galaxies

Participants are not required to identify specific galaxies with their Messier/NGC numbers

1. Recall the size and structure of the Milky Way, such as distribution of star clusters
2. Describe the density wave model of spiral arms and how it results in stellar formation
3. Account for the rotation curve of galaxies via the idea of dark matter
4. Recall the Shapley-Curtis Debate and differing arguments from each side
5. Give a brief account of Hubble's classification in his tuning fork diagram as well as various types of galaxies.
6. Be familiar with galaxy clusters and the Local Group
7. Understand the processes behind galaxy mergers, collisions, and interactions, as well as how this affects galaxy evolution.
7. Understand the mechanism of radio galaxies with active galactic nuclei
8. Account for radio lobes and galactic jets with superluminal motion
9. Distinguish between Seyfert galaxies, quasars and blazars

10. Understand the difference between hot dark matter and cold dark matter, and their significance in the formation of galaxies
11. Be familiar with Superclusters and voids in the cosmic sense

Cosmology

Participants are not required to focus on speculative theories such as Parallel Universes or the Oscillatory Universe Model. Topics that are linked closely with particle physics such as The Standard Model or string theory will not be covered as well.

1. Compare the merits and demerits of Big Bang Theory and Steady State Theory
2. Have an understanding of the fundamental forces of the universe and their roles in the Big Bang Theory.
3. Understand Olbers' Paradox and its resolution
4. Appreciate the significance of the cosmological principle
5. Understand that the fate of the Universe depends on critical density and entropy
6. Appreciate the importance of the cosmic microwave background radiation
7. Understand the theory of inflation and why it was required
8. Resolve the flatness problem and horizon problem
9. Appreciate the cosmological constant and its relation to dark energy
10. Describe and differentiate potential explanations for dark matter
11. Appreciate the use of non-optical telescopes to detect gravitational waves

Life in the Universe/SETI/METI

Participants are encouraged to have a good biological background in regards with this topic and should understand the conditions for life in relation to an astronomical setting. Memorising of specific exoplanets are not required.

1. Understand why Earth is the most suitable planet for life
2. Appreciate the different theories for the origin of life on Earth
3. Understand the risks due to near-earth asteroids
4. Appreciate Drake's equation and its significance in relation to extraterrestrial life (memorisation of formula is not required)
5. Appreciate the importance of the Carbon atom to life
6. Understand why the water-hole region may be used for communication
7. Appreciate the strong/weak anthropic principle

Practical astronomy

Participants are encouraged to be exposed to amateur astronomy as a hobby and be familiar with its equipment and terms. Handling of a telescope is required during the Observation Round for seniors.

1. Discuss the designs, merits and demerits of various telescope designs and mounts
2. Describe the property of images formed through optical elements of an astronomical set-up
3. Understand that light gathering power is dependent on aperture, not magnification; calculate resolving power using Rayleigh criterion and Dawes' limit
4. Show a basic understanding of astrophotography and associated techniques
5. Understand the terms field of view, eye relief and exit pupil and other related terms
6. Appreciate the use of telescope accessories
7. Demonstrate an understanding of focal length and focal ratio (speed rating) of a telescope
8. Understand factors that determine magnification
9. Describe how certain aberrations could be minimized or prevented
10. Be familiar with common naked-eye, binocular or telescope targets often seen from Singapore throughout the year
11. Be able to produce a simple sketch of object seen through the eyepiece, including its observed details
12. Know common procedures for maintenance of astronomical equipments
13. Be familiar with the use of star-charts/planispheres, declination and right ascension with respect to equatorial mounts
14. Describe different methods and the significance of polar alignment