



**Harvard Undergraduate Science Olympiad India  
2025 Final Round  
9-10th Grade  
Earth Science Section: Questions**

**Instructions:**

The Earth Science exam will be divided into 5 categories: Interior of the Earth, Minerals & Rocks, Astronomy & Astrophysics, Hydrosphere, and Atmosphere. Each category will contain 5 multiple-choice questions (with 1,2,3 or 4 correct answers) and one open-ended question.

You may spend 1 hour on the Earth Science exam. You are allowed a non-programmable, non-graphing calculator. No additional notes or electronics are allowed. Make sure you have received **all 8 pages of this exam**.

**Grading:**

Each multiple choice question is worth 1 point, and the open-ended question is worth 5 total points, with each sub-part worth equally (e.g: if there are 2 parts, each part is worth 2.5 points; alternatively, if there are 5 parts, each part is worth 1 point).

In case of a tie, the higher cumulative score on the open-ended questions will be the tie-breaker.

It is within your best interest to attempt all questions: **no points will be taken off for incorrect answers**.

*Best of luck! You've got this!*

## Interior of the Earth Section

### Multiple Choice Questions (1,2,3 or 4 answers may be correct):

- Which of the following statements about the Earth's interior are correct?
  - The crust is the thinnest layer of the Earth
  - The mantle is composed mainly of molten iron and nickel
  - The outer core is in a liquid state
  - The inner core has extremely high temperature and pressure
- At which type of plate boundary do plates slide past each other without creating or destroying crust?
  - Convergent boundary
  - Divergent boundary
  - Transform boundary
  - Subduction zone
- Which seismic waves can travel through the Earth's interior?
  - P-waves
  - S-waves
  - Love waves
  - Rayleigh waves
- Which properties are typical of sandy soils?
  - High water-holding capacity
  - High nutrient retention
  - Large particle size
  - Good drainage
- Which statements about the Earth's crust are correct?
  - The crust forms the Earth's outermost layer
  - Continental crust is thicker than oceanic crust
  - The crust is composed mainly of iron and nickel
  - Oceanic crust is denser than continental crust

### Open-ended Question:

- What is the name of the boundary between the mantle and the crust of the Earth?  
Mohorovičić / Moho Discontinuity
- What is subduction?  
The process in which one tectonic plate slides under another tectonic plate
- Name 3 of the 7 major tectonic plates.  
Any 3 of the following: Pacific, North American, Eurasian, African, Antarctic, Indo-Australian (can be split into Indian and Australian), and South American.
- What is the name of the initial supercontinent of the world?  
Pangaea/Pangea
- Name one of the four driving forces behind plate motion.  
Convection, slab pull, ridge push, gravitational sliding

## Minerals & Rocks Section

### Multiple Choice Questions (1,2,3 or 4 answers may be correct):

1. Which one(s) of the following igneous rocks is fine-grained?
  - A. Granite
  - B. Basalt**
  - C. Diorite
  - D. Andesite**
2. Which of the following are sedimentary rocks?
  - A. Sandstone**
  - B. Limestone**
  - C. Chalk**
  - D. Gypsum**
3. Which of the following is true about metamorphic rocks?
  - A. Metamorphic rocks are the products of preexisting rocks that suffered high pressure/temperatures**
  - B. Some examples of metamorphic rocks are gneiss and schists**
  - C. Magmas that erupt on the Earth's surface produce extrusive metamorphic rocks
  - D. Carbon dioxide can act as an agent for turning sedimentary rocks into metamorphic rocks
4. Which of the following are part of Bowen's Reaction Series?
  - A. Olivine**
  - B. B. Quartz**
  - C. C. Calcite
  - D. D. Pyroxene**
5. Which of the following are physical or optical properties used to identify minerals?
  - A. Opacity**
  - B. Luster**
  - C. Density (specific gravity)**
  - D. Latitude of formation

### Open-ended Question:

1. What are the 4 types of igneous rocks based on their composition (proportion of light and dark minerals)?  
**Granitic (Felsic), Andesitic, Basaltic (Mafic), Ultramafic**

**Astronomy and Astrophysics Section:**

**Multiple Choice Questions** (1,2,3 or 4 answers may be correct):

- The Doppler effect causes light from a star moving away from Earth to:  
 A. Shift toward red wavelengths  
 B. Increase in brightness  
 C. Shift toward blue wavelengths  
 D. Change frequency
- Which star-constellation pairs are correct?  
 A. Polaris - Ursa Major  
 B. Vega - Lyra  
 C. Sirius - Canis Major  
 D. Arcturus - Boötis
- Planet A has an albedo of 0.1, and Planet B has an albedo of 0.6. Which statements are correct?  
 A. Planet A absorbs more sunlight  
 B. Planet B reflects more sunlight  
 C. Planet A absorbs 90% of incoming light  
 D. Planet B absorbs 60% of incoming light
- Star A has an apparent magnitude of  $m_A = -1.5^m$  and star B has  $m_B = 1^m$ . Which statements are always correct?  
 A. Star B appears 10 times brighter than star A  
 B. Star A has a bigger luminosity than Star B  
 C. Star A appears 10 times brighter than star B  
 D. Star B is further away from the observer than star A
- An observer is at 60° N latitude. Which declinations correspond to stars that are circumpolar for this observer?  
 A. +20°  
 B. +25°  
 C. +35°  
 D. +60°

**Open-ended Question:**

For this part, you are given the following constant:

Constant name:	Value:	Unit:
Wien's displacement constant	$2.898 \times 10^{-3}$	m × K

1. A star has a parallax angle of 0.2 arcseconds. Find its distance in parsecs.  
 $d=1/p=5$  parsecs
2. The peak wavelength of Star A's emission is 400 nm and the peak wavelength of Star B's emission is 800 nm. Both can be modeled as black bodies. Determine which star has the larger surface temperature and compute the ratio  $T_A/T_B$ .  
Temperature is proportional to  $1/\lambda$  → Star A is twice as hot as star B.
3. A geostationary satellite remains fixed above one point on Earth's equator, so its orbit is circular in the equatorial plane and its orbital period equals Earth's rotation period. Assume Earth is spherical with radius  $R_E = 6.37 \times 10^6$  m and surface gravity  $g = 9.81$  m/s<sup>2</sup>. Take Earth's rotation period to be  $T = 23$  h 56 min. Calculate the satellite's altitude  $h$  above Earth's surface.

For a circular geostationary orbit, the gravitational acceleration is equal in magnitude to the centripetal acceleration:  $GM / r^2 = \omega^2 r$ , with  $\omega = 2\pi / T$ .

Using  $GM = g R_E^2$ , this gives  $r^3 = (g R_E^2) / \omega^2 = (g R_E^2 T^2) / (4\pi^2) \approx 4.21 \times 10^7$  m. The altitude above Earth's surface is:  $h = r - R_E \approx 4.21 \times 10^7 - 6.37 \times 10^6 \approx 3.58 \times 10^7$  m  $\approx 3.58 \times 10^4$  km. So the geostationary satellite is about  $3.58 \times 10^4$  km ( $\sim 35,800$  km) above Earth's surface.

4. Two stars A and B orbit their common center of mass in a circular, edge-on binary with period  $P=30$  days. The center of mass of the system moves away from Earth with speed  $v_{\text{sys}} = 20.0$  km/s. Relative to the center of mass, star A has line-of-sight speed  $v_A = 30.0$  km/s and star B has line-of-sight speed  $v_B = 60.0$  km/s (these are the maximum speeds over an orbit). A spectral line from star A has a rest wavelength  $\lambda_0 = 500.0$  nm. Assume  $v \ll c$ .

Find the mass ratio  $M_B/M_A$ , the orbital radii  $a_A$  and  $a_B$ , the total separation  $a$ , and the individual masses  $M_A$  and  $M_B$ . What is the maximum wavelength displacement  $|\Delta\lambda|$  from  $\lambda_0$  that an observer on Earth can measure for star A over one full orbit?

$$a_A = v_A P / (2\pi) \approx (30.0 \text{ km/s})(30.0 \text{ d}) / (2\pi) \approx 1.24 \times 10^{10} \text{ m}$$

$$a_B = v_B P / (2\pi) \approx (60.0 \text{ km/s})(30.0 \text{ d}) / (2\pi) \approx 2.48 \times 10^{10} \text{ m}$$

$$a = a_A + a_B \approx 3.71 \times 10^{10} \text{ m} \approx 0.248 \text{ AU}$$

$$\text{Using Kepler's 3rd law: } M_A + M_B = 4\pi^2 a^3 / (G P^2) \approx 4.51 \times 10^{30} \text{ kg} \approx 2.27 M_{\text{sun}}$$

$$M_B v_B = M_A v_A \Rightarrow M_B / M_A = 0.50, \text{ we have } M_A + M_B = 1.5 M_A, \text{ so:}$$

$$M_A \approx (4.51 \times 10^{30} \text{ kg}) / 1.5 \approx 3.00 \times 10^{30} \text{ kg} \approx 1.51 M_{\text{sun}}$$

$$M_B \approx 0.50 M_A \approx 1.50 \times 10^{30} \text{ kg} \approx 0.755 M_{\text{sun}}$$

Maximum wavelength displacement for star A over the orbit: the largest line-of-sight speed away from Earth is  $v_{\text{sys}} + v_{\text{A}} = 20 + 30 = 50 \text{ km/s}$ , so

$|\Delta\lambda|/\lambda_0 = v/c \Rightarrow |\Delta\lambda| = \lambda_0 (v/c) = 500.0 \text{ nm} \times (50/3.0 \times 10^5) \approx 0.083 \text{ nm}$ . Maximum  $|\Delta\lambda| \approx 0.083 \text{ nm}$ .

## Hydrosphere Section

### Multiple Choice Questions (1,2,3 or 4 answers may be correct):

- Which of the following is true about the hydrosphere?
  - Most of the world's freshwater is represented by glaciers
  - Glaciers form from compacted snow
  - Aquifers represent permeable rock strata or sediments that transmit groundwater freely
  - Areas that have been shaped by the dissolving power of groundwater are said to exhibit "karst topography"
- Which of the following are important steps of the Hydrologic Cycle?
  - Precipitation
  - Evaporation
  - Volcanic eruption
  - Decalcification
- Which of the following are types of wetlands?
  - Marsh
  - Swamp
  - Bog
  - Desert
- Which statements are correct?
  - Most ocean waves are caused by wind
  - Tides are influenced by the Moon's gravity
  - Tsunamis are the same as normal waves
  - Tsunamis are caused by underwater earthquakes
- Which of the following are types of ocean sediments?
  - Sand and mud from land
  - Shells of marine organisms
  - Lava flows
  - Sediment formed from chemicals in seawater

### Open-ended Question:

- What is the freshwater discharge (Q) if the Cross-Sectional Area (A) of a river is 10 m<sup>2</sup> and the Average Velocity (V) of the river is 20 m/s? Make sure to show your work and write down the units of your answer.

$$Q=A*V=200\text{m}^3/\text{s}$$

### Atmosphere Section:

#### Multiple Choice Questions (1,2,3 or 4 answers may be correct):

1. Which layer of the atmosphere contains the ozone layer?
  - A. Troposphere
  - B. Stratosphere**
  - C. Mesosphere
  - D. Thermosphere
2. What type of front is formed when a warm air mass moves over a cold air mass?
  - A. Cold front
  - B. Stationary front
  - C. Warm front**
  - D. Occluded front
3. Which winds are caused by differences in temperature between land and sea?
  - A. Trade winds
  - B. Sea breezes**
  - C. Westerlies
  - D. Land breezes**
4. What factors influence the formation of precipitation?
  - A. Humidity**
  - B. Temperature**
  - C. Cloud type**
  - D. Air pressure**
5. Which statements about El Niño and La Niña are true?
  - A. El Niño warms the Pacific Ocean**
  - B. La Niña cools the Pacific Ocean**
  - C. Both affect global weather patterns**
  - D. Only occur in the Atlantic Ocean

#### Open-ended Question:

1. What is the term for a large system of rotating low pressure?  
**Cyclone**
2. Which cloud type is thin, wispy, and found at high altitudes?  
**Cirrus**
3. What do we call a sudden reversal of normal temperature with height in the atmosphere?  
By normal we mean that warm air sits below cooler air.  
**Thermal inversion**
4. Name 2 layers of the atmosphere in which the phenomenon from open-ended question part 3 occurs.  
**Troposphere, Stratosphere, Thermosphere**