

Indian National Astronomy Olympiad – 2010

Senior Category
Question Paper

Roll Number:

INAO – 2010
Duration: **Three Hours**

Date: 30th January 2010
Maximum Marks: 100

Please Note:

- Please write your roll number on top of this page in the space provided.
- Before starting, please ensure that you have received a copy of the question paper containing total 3 pages (6 sides).
- In Section A, there are 10 multiple choice questions with 4 alternatives out of which only 1 is correct. You get 3 marks for each correct answer and **-1 mark for each wrong answer**.
- In Section B, there are 4 multiple choice questions with 4 alternatives each, out of which any number of alternatives may be correct. You get 5 marks for each correct answer. No marks are deducted for any wrong answers. **You will get credit for the question if and only if you mark all correct choices and no wrong choices**. There is no partial credit.
- For both these sections, you have to indicate the answers on the page 2 of the answersheet by putting a × in the appropriate box against the relevant question number, like this:

Q.NO.	(a)	(b)	(c)	(d)	OR	Q.NO.	(a)	(b)	(c)	(d)
22	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		35	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Marking a cross (×) means affirmative response (selecting the particular choice). Do not use ticks or any other signs to mark the correct answers.

- In Section C, there are 5 analytical questions totalling 50 marks.
- Blank spaces are provided in the question paper for the rough work. No rough work should be done on the answer-sheet.
- No computational aides like calculators, log tables, slide rule etc. are allowed.
- **The answer-sheet must be returned to the invigilator**. You can take this question booklet back with you.

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION

Tata Institute of Fundamental Research

V. N. Purav Marg, Mankhurd, Mumbai, 400 088

Useful Physical Constants

Mass of the Earth	$M_E \approx 5.97 \times 10^{24} \text{ kg}$
Radius of the Earth	$R_E \approx 6.4 \times 10^6 \text{ m}$
Mass of the Sun	$M_\odot \approx 1.99 \times 10^{30} \text{ kg}$
Radius of the Sun	$R_\odot \approx 7 \times 10^8 \text{ m}$
Radius of the Moon	$R_m \approx 1.7 \times 10^6 \text{ m}$
Speed of Light	$c \approx 3 \times 10^8 \text{ m/s}$
Astronomical Unit	1 A. U. $\approx 1.5 \times 10^{11} \text{ m}$
Gravitational Constant	$G \approx 6.67 \times 10^{-11} \text{ m}^3/(\text{Kg s}^2)$
Speed of Sound in Air	$c_s \approx 330 \text{ m/s}$
Inclination of the Earth's Axis	$\epsilon \approx 23.5^\circ$

Space for Rough Work

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION

Tata Institute of Fundamental Research

V. N. Purav Marg, Mankhurd, Mumbai, 400 088

Section 1: Multiple Choice Questions

Part A: (10 Q × 3 marks each)

- As seen from the Earth, the stars appear to twinkle, while the planets do not because,
 - Light coming from the stars gets absorbed by interstellar dust.
 - the stars are self luminous while the planets merely reflect the light.
 - Angular sizes of the stars are much smaller than the planets.
 - All the above.

A wooden cube of length 5 units is painted on all faces and then cut in 85 smaller cubes of varying sizes. The sides of each of the smaller cubes are some integer number of units. All bigger cubes are carved out of the corners of the original cube. Answer the following three questions:

- How many cubes have no side painted?
A. 15 B. 17 C. 20 D. 27
- How many cubes have exactly 2 sides painted?
A. 24 B. 27 C. 30 D. 36
- If one was to cut the original cube (of size 5 units each side) with a condition that all corners would be occupied by the cubes bigger than 1 unit size, what will be the smallest total of cube pieces possible?
A. 69 B. 64 C. 62 D. 50
- It is easier to balance on a faster bicycle moving along a straight line than a slower one because of
 - conservation of linear momentum
 - conservation of angular momentum
 - conservation of linear momentum and angular momentum
 - conservation of energy
- On a nice sunny day in Chennai, Akshay saw a supersonic fighter plane flying parallel to the ground in the sky. As a student of Aeronautical Engineering, he knew off-hand the speed of the plane to be 1.25 Mach (i.e. 1.25 times the speed of sound in air). He could hear its sonic boom, 12 seconds after the plane flew directly overhead. What is the altitude of the plane?
A. 3.7 Km B. 4.0 Km C. 5.3 Km D. 6.6 Km
- If you hold a magnifying glass of focal length 10 cm in the sunlight and place a piece of paper at its focus, you can burn a hole in the paper. What could be the size of this hole?
A. 10 mm B. 5 mm C. 0.5 mm D. 0.1 mm

8. During an earthquake, an earthquake monitoring centre observed that transverse waves travelling with speed 4.5 km/s arrived at the centre 3 minutes after the longitudinal waves travelling at 8.2 km/s. Deduce the approximate distance to the epicenter.
A. 60 km B. 220 km C. 660 km D. 1800 km
9. A certain person nicknamed “Enthu”, encountered an automatic staircase (i.e. escalator) at a shopping complex, which was moving upward at a constant rate. Just for the fun of it he decided to walk up this escalator at the rate of one step a second. Twenty steps brings him to the top. Next day he goes up at two steps a second and reaching the top in 32 steps. How many steps are there in the escalator?
A. 40 B. 60 C. 64 D. 80
10. Two stars of masses M and $3M$ respectively are going around each other, in near circular orbits, with period T . The separation between them is given by $D = \sqrt[3]{\frac{kGMT^2}{\pi^2}}$. The value of k is,
A. 0.5 B. 1 C. 1.5 D. 3

Section B: (4 questions \times 5 marks each)

11. If we throw a ball in a shallow water tank, propagation velocity of ripples on surface of the water will depend on
A. surface tension of the water
B. depth of the water tank
C. density of the water
D. height from which the ball was dropped
12. Amit decided to experiment with cannon ball by making it hollow and filling water inside it. He then punched few holes in it. After the ball was fired horizontally, he was expecting to see water jets coming out from some of the holes. Which of the following locations of holes will allow water jet to come out?
A. Front, bottom and sides B. Back, top and sides C. back and bottom
D. None of the holes
13. In the progress of Astronomy over the ages, we find several instances of startling new observations changing our ideas about the Universe and lead to new theories. Listed below are some milestones in the history of Astronomy and observations which necessitated them. Pick the correct statement(s).
A. Ptolemy was aware of retrograde motion of planets when he gave his model of the solar system.
B. Newton was aware of Kepler’s Laws when he gave his Law of Gravitation.
C. Einstein felt need to modify Newton’s theory of Gravitation to explain the expansion of the Universe.
D. Existence of Cosmic Microwave Background Radiation (CMBR) led to the creation of the Big Bang Theory.

14. Two simple pendula are hung close to each other on a thin, rigid support and are allowed to oscillate independently in planes parallel to each other. They have periods 3 seconds and 7 seconds respectively with same amplitudes and are initially released from the opposite extreme positions of each other. At which of the following times the threads of the two pendula will be coplaner again?
- A. 1.05 seconds B. 7.88 seconds C. 10.50 seconds D. 23.10 seconds

Section C: Analytical Questions

- α . An alien civilisation on a star far far away came to know about the Astronomy Olympiad Examination and wanted to test smartness of the students. They sent following two coded secret messages. Decode them.

(a) (5 marks) First is a pictorial message in black and white colour. They sent it on radio waves in the form of ones and zeros. Find out what the picture says.

00000 00000 00000 00000 00000 00000 11111 01100 00100 00100 00011
 10000 01000 10100 01000 10100 01101 10000 10001 00100 10001 11000
 10001 00001 00010 00101 00100 01001 10110 01111 10100 00110 10000
 01001 11000 00000 00000 00000 00000 00000 000

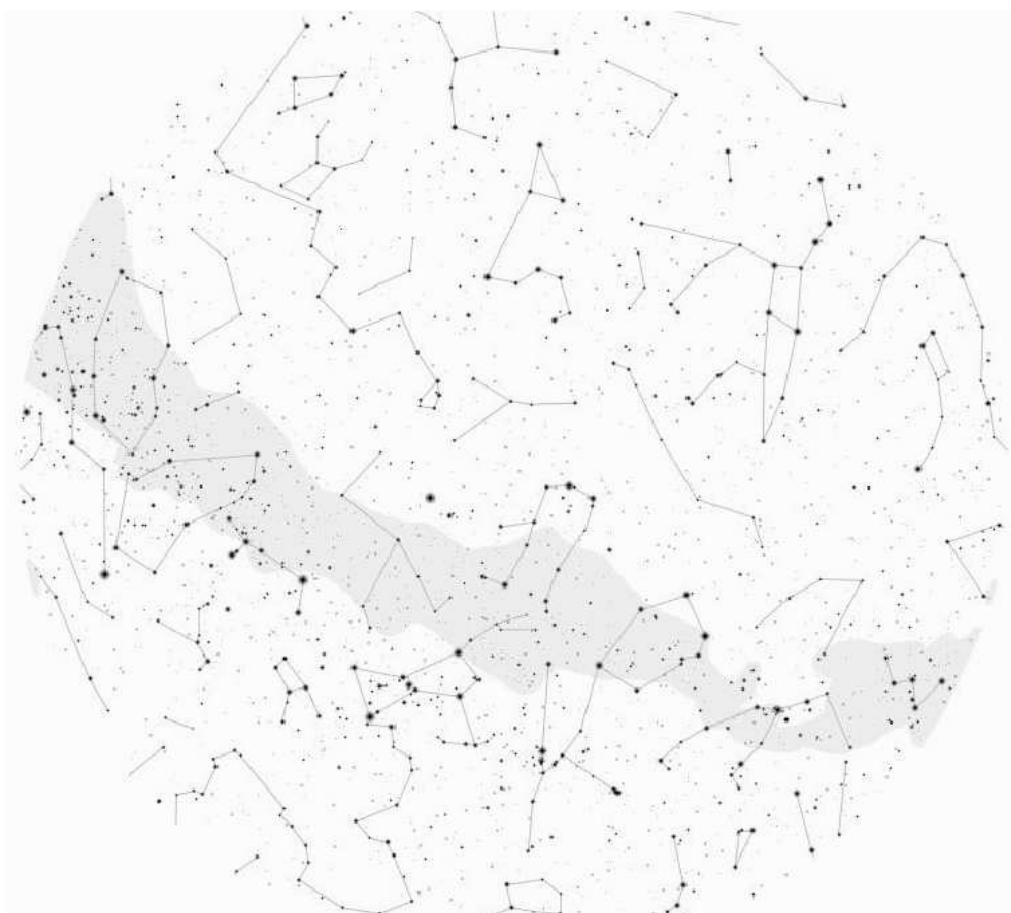
(b) (5 marks) Surprisingly, the aliens are also proficient in English and the following coded message is actually a sentence in English language. In the answersheet, write down the coded sentence and also the true meaning of each alphabet in the code.

“Up tpmwf uif qsfwjvpt tvcrvftujpo uijol pg uif nfttbhf tfou cz uif bsfdjcp ufmftdpqf up bmjtot.”

- β . (8 marks) In the following table, the first column gives various optical phenomena / instruments and the top row gives various optical effects which may help in explaining them. In the answers sheet, tick the correct effect(s) involved in each phenomena in appropriate rows.

	Appreciable Dispersion	Internal Reflection	Reflection	Refraction	Scattering
Blue Sky					
Mirage					
Rainbow					
Smooth Convex Mirror					
Thick Concave Lens					

- γ . Study the following image of the night sky (bigger version is printed in your answer-sheet) for mid-night on a certain day at a certain place and answer the questions below it. All answers must be marked / written on the answer-sheet.

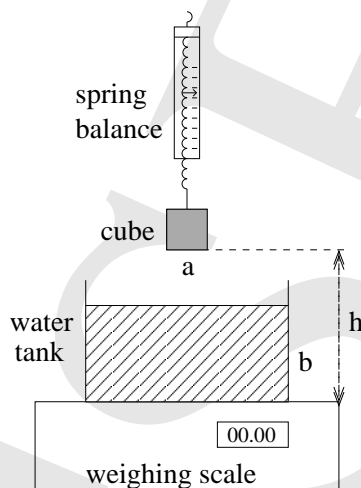


- (a) (2 marks) Mark all the four directions on the map.
- (b) (1 mark) Is this place in northern part of India or the southern part?
- (c) (3 marks) Mark and name 2 constellations each from the following two lists:
- **0.5 marks each; any 2:** Orion, Ursa Major, Taurus, Leo, Cygnus, Scorpio
 - **1 mark each; any 2:** Hydra, Corvus, Aquarius, Cancer, Canis Major, Aries
- (d) (2 marks) Sketch rough band of ecliptic i.e. apparent path of the Sun, the Moon and all the planets in the sky.
- (e) (2 marks) In which month the sky will appear like this at this time? Give reason in one line.
- δ. Mayank visited a place located at latitude ϕ and longitude $82.5^\circ E$ on 21st June. He observed that at local noon, shadow of a one meter stick standing vertically on the ground was 26.8 cm long due south.
- (a) (5 marks) Find latitude of the place.
- (b) (5 marks) Find the day on which the shadow of this stick at the local noon will be longest and find length and direction of that shadow.

Note: $\sin^{-1}(0.268) = 15.5^\circ$, $\cos^{-1}(0.268) = 74.5^\circ$, $\tan^{-1}(0.268) = 15.0^\circ$, $\tan(2^\circ) \approx \frac{1}{30}$ and $\sqrt{3} = 1.73$

ε. Sketch approximate graphs for the following situations:

- (a) (4 marks) See the figure below. A tank of water (height of water column b) is kept on a electronic weighing scale. A metal cube (side a and density ρ) is hung from a spring balance and the spring balance is slowly lowered into the tank till the cube reaches the bottom of the tank. The distance of separation between the bottom of the tank and bottom of the cube is denoted by h with initial value h_0 .



Sketch the graph of reading on the spring balance as a function of h .

- (b) (3 marks) For the situation above, sketch the graph of reading on the electronic scale as a function of h .
- (c) (2 marks) For the situation above, sketch the graph of sum of the reading on the electronic scale and the reading on the spring balance as a function of h .
- (d) (3 marks) For a typical primary mirror used in Newtonian telescope, sketch a graph of object distance, u versus image distance, v . All physically measurable lengths should be taken as positive.

In all cases, mark the significant points on the graph and give their coordinates.

Space for Rough Work

INAO – Sr – 2010