41

Time: 9:00 AM to 10:15 AM

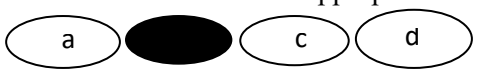
Question Paper Code: 41

Roll No. of Student's														

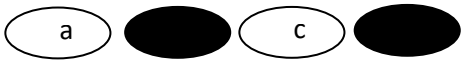
Write the question paper code (mentioned above) on YOUR OMR Answer Sheet (in the space provided), otherwise your Answer Sheet will NOT be evaluated.
Note that the same Question Paper Code appears on each page of the question paper.

Instructions to Candidates:

1. Use of mobile phone, smart watch, and iPad during examination is STRICTLY **PROHIBITED.**
2. In addition to this question paper, you are given OMR Answer Sheet along with Candidate's copy.
3. On the OMR sheet, make all the entries carefully in the space provided **ONLY** in **BLOCK CAPITALS** as well as by properly darkening the appropriate bubbles.
   Incomplete/ incorrect/carelessly filled information may disqualify your candidature.
4. On the OMR Answer Sheet, use only **BLUE or BLACK BALL POINT PEN** for making entries and filling the bubbles.
5. Your **14-digit roll number and date of birth** entered on the OMR Answer Sheet shall remain your login credentials means login id and password respectively for accessing your performance / result in Indian Olympiad Qualifier in Astronomy 2021-22 (Part I).
6. Question paper has two parts. In part A - 1 (Q. No.1 to 24) each question has four alternatives, out of which **only one** is correct. Choose the correct alternative and fill the appropriate bubble, as below

Q.No.12 

In part A - 2 (Q. No. 25 to 32) each question has four alternatives out of which any number of alternative(s) (1, 2, 3, or 4) may be correct. You have to choose **all** correct alternative(s) and fill the appropriate bubble(s), as shown

Q.No.30 

7. For **Part A - 1,** each correct answer carries 3 marks whereas 1 mark will be deducted for each wrong answer. In **Part A - 2,** you get 6 marks if all the correct alternatives are marked and no incorrect. No negative marks in this part.
8. Rough work should be done in the space provided. There are **07** printed pages in this paper
9. Use of **non - programmable scientific** calculator is allowed.
10. No candidate should leave the examination hall before the completion of the examination.
11. After submitting answer paper, take away the question paper & Candidate's copy OMR sheet for your reference.

Please DO NOT make any mark other than filling the appropriate bubbles properly in the space provided on the answer sheet.

Answer sheets are evaluated using machine, hence CHANGE OF ENTRY IS NOT ALLOWED. Scratching or overwriting may result in a wrong score.

DO NOT WRITE ON THE BACK SIDE OF THE ANSWER SHEET.

Instructions to Candidates (Continued) :
You may read the following instructions after submitting the answer sheet.

12. **Comments/Inquiries/Grievances regarding this question paper, if any, can be shared on the Inquiry/Grievance column on www.iapt.org.in on the specified format till January 29, 2022.**
13. **The answers/solutions to this question paper will be available on the website: www.iapt.org.in by January 27, 2022.**

14. **CERTIFICATES and AWARDS:**
Following certificates are awarded by IAPT to students, successful in the Indian Olympiad Qualifier in Astronomy 2021-22 (Part I)
(i) "CENTRE TOP 10 %" To be downloaded from iapt.org.in after 15.03.22
(ii) "STATE TOP 1 %" Will be dispatched to the examinee
(iii) "NATIONAL TOP 1 %" Will be dispatched to the examinee
(iv) "GOLD MEDAL & MERIT CERTIFICATE" to all students who attend OCSC – 2022 at HBCSE Mumbai
Certificate for centre toppers shall be uploaded on iapt.org.in

15. List of students (with centre number and roll number only) having score above MAS will be displayed on the website: **www.iapt.org.in** by **February 06, 2022. See the Minimum Admissible Score Clause** on the student's brochure on the web.
16. List of students eligible for evaluation of IOQA 2021-22(Part II) shall be displayed on www.iapt.org.in by February 10, 2022.

Physical constants you may need….

Magnitude of charge on electron $e = 1.60 \times 10^{-19} C$	Avogadro's constant $A = 6.023 \times 10^{23} mol^{-1}$
Mass of electron $m_e = 9.10 \times 10^{-31} kg$	Speed of light in free space $c = 3.0 \times 10^8$ m/s
Mass of proton $m_p = 1.67 \times 10^{-27} kg$	Permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12} C^2 / Nm^2$
Acceleration due to gravity g = 9.81 ms^{-2}	Permeability of free space $\mu_0 = 4\pi \times 10^{-7} H / m$
Universal gravitational constant $G = 6.67 \times 10^{-11} Nm^2 / Kg^2$	Planck's constant $h = 6.63 \times 10^{-34} Js$
Universal gas constant $R = 8.31 J / mol K$	Faraday constant $= 96,500 C / mol$
Boltzmann constant $k = 1.38 \times 10^{-23} J / K$	Rydberg constant $R = 1.097 \times 10^7 m^{-1}$
Stefan's constant $\sigma = 5.67 \times 10^{-8} W / m^2 K^4$	

ASTRONOMY 2021-22 (Part I) (NSEA 2021 – 22)

Time: 75 minute **Max. Marks: 120**

Attempt All Thirty Two Questions

A – 1

ONLY ONE OUT OF FOUR OPTIONS IS CORRECT. BUBBLE THE CORRECT OPTION.

1. Two balls of masses m_1 and m_2 respectively ($m_1 > m_2$) are projected towards each other from initial separation d at t = 0 such that their motion is in the same plane. Initial velocity of each ball is v facing towards each other at an angle 45^0 from the horizontal. The two balls undergo completely inelastic collision, and fuse to form a single body of mass $m_1 + m_2$. The total time t (counting from t = 0) after which the fused body will fall to the ground (neglecting air resistance) is

   (a) $\frac{v\sqrt{2}}{g}$ (b) $\frac{m_1 v\sqrt{2}}{g(m_1+m_2)}$ (c) $\frac{v}{g\sqrt{2}}$ (d) $\frac{(m_1+m_2)v}{m_1 g\sqrt{2}}$

2. The solution for $\frac{dy}{dx} + y = Ae^{-x}$ for y(1) = 5 is (here A is constant)

   (a) $\frac{1}{5}e^{-x}$ (b) $[5e + A(x-1)]e^{-x}$

   (c) $[5e - A(x-1)]e^{-x}$ (d) $[5e]e^{-x}$

3. A 1-inch telescope is pointed towards Sirius (m = – 1.4) and another bigger one towards Castor (m = 1.6), m being the apparent magnitude, but both the telescopes deliver equal amount of energy per second to the CCD detector at the eyepiece. The objective diameter of the bigger telescope is (using $\log_{10} 2 = 0.3$)

   (a) 2 - inch (b) 4 - inch (c) 8 - inch (d) 16 - inch

4. Consider a circle circumscribing an equilateral triangle of side L. The ratio of the area of the circle to that of the equilateral triangle is

   (a) $\frac{\pi}{2\sqrt{3}}$ (b) $\frac{4\pi}{3\sqrt{3}}$ (c) $\frac{\pi}{\sqrt{3}}$ (d) $\frac{6\pi}{\sqrt{3}}$

5. A light ray having frequency f and wavelength λ enters from air into water. After entering into water, its

   (a) f remains unchanged, λ decreases (b) f increases and λ decreases

   (c) f decreases, λ remains unchanged (d) f and λ both decrease

6. A lens of diameter d and focal length f is used to project image of an object on a screen. The object is kept at a distance u from the lens and consists of two points separated by distance r_o in the plane perpendicular to the principal axis. The wavelength of light used is λ. The two points will be resolved in the image if

   (a) $u < \frac{1.22\,\lambda r_o}{d}$ (b) $d > \frac{1.22\,\lambda f}{r_o}$

   (c) $u < \frac{r_o\, d}{1.22\,\lambda}$ (d) $d > \frac{1.22\,\lambda u\, r_o}{f}$

7. Assume that the density (ρ) of the earth has following dependence on the distance r from the centre $\rho(r) = \rho_0$ for $r < r_0$,
$\rho(r) \propto \frac{1}{r}$ for $r_0 \leq r \leq R$,
R being earth's radius and ρ_0 is constant density of the central core. For any point r between r_0 and R, the gravitational acceleration g(r) will have the following form (A and B being constants in the following)
(a) $A + \frac{B}{r^2}$ (b) Ar (c) $\frac{A}{r} + Br$ (d) $A + Br$

8. Given $f(x)$ is a continuous function such that for $x \leq 1$, $f(x) = 5e^{-(x-1)^2}$ and for $x \geq 1$, $f(x) = \frac{K}{(x+4)^2}$.
The value of K is
(a) $\frac{1}{5}$ (b) 5 (c) 25 (d) 125

9. The geometric albedo (A) of the solar system objects is related to their absolute magnitude (M) and diameter (D) as $A = \left(\frac{1329 \times 10^{-M/5}}{D}\right)^2$. Initially it was thought that the radius of Phobos, one of the satellites of Mars, is 7 km assuming the albedo of Phobos is same as that of Mars i.e. about 0.15. But later Mariner spacecraft's photographs revised the radius to 10 km. The correct albedo of Phobos, therefore, is
(a) 0.10 (b) 0.05 (c) 0.07 (d) 0.12

10. The area in the region $1 \leq x \leq 2$ between the line $y = 2x + 10$ and the curve $y = 3x^2$ is (x and y are in cm and area is in cm^2)
(a) 6 (b) 5 (c) 7 (d) 8

11. The summer triangle refers to the three stars
(a) Vega, Altair and Deneb (b) Regulus, Antares and Sirius
(c) Sirius, Procyon and Betelgeuse (d) Pollux, Caster and Regulus

12. The three points (1, 0, 5), (2, 3, 1) and (4, 9, r) are collinear. The value of r is:
(a) 12 (b) – 14 (c) – 7 (d) 0

13. Astronomers have discovered 200 stars having parallax of $0.10''$ with fair completeness. Supposing the distribution of stars around us is pretty much homogeneous and isotropic, the number of stars having parallaxes $0.025''$ or more is
(a) 3200 (b) 25600 (c) 12800 (d) 6400

14. The value of (x, y) for which $z = 3x + 4y + 10$ is a maximum under the constraints $x + y \leq 40$, $2x + 3y \leq 90$, $x, y \geq 0$ is
(a) (0, 30) (b) (0, 40) (c) (40, 0) (d) (30, 10)

15. Kepler's laws for planetary orbits are derived using Newton's law of gravitational force. These laws state that
First: All planets move in elliptical orbit with sun at one of the foci,
Second: The line joining the planet to the sun sweeps equal area in equal time interval,
Third: Square of the period of revolution of a planet is proportional to cube of semi-major axis.
Newton's law of gravitation receives corrections from relativity theory, with the modified law of force between bodies of masses M and m at a distance r given by
$$\vec{F} = -\frac{GMm}{r^2}\left(1 + \frac{A}{r^2}\right)\hat{r}$$
where A is some constant. With this correct form of law of gravitation, for which of the Kepler's laws you can be sure that it (these) will remain unchanged.
(a) First and Second (b) First (c) Second (d) All laws will change

16. Globular clusters in our galaxy are primarily found:
(a) in the spiral arms.
(b) distributed throughout the disk including regions between the spiral arms.
(c) in the bulge at the center of our galaxy.
(d) in the halo of our galaxy

17. **C**onsider the function $\prod_{n=1}^{\infty} \frac{1}{1-x^n}$. What is the coefficient of x^5 in its expansion near x = 0
(a) 7 (b) 5 (c) 3 (d) 10

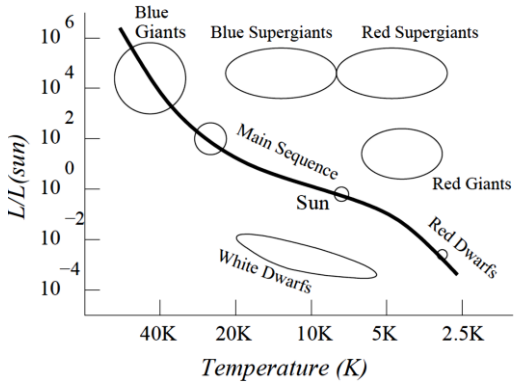
18. If a and b are roots of $x^2 - 6x + p = 0$ and c and d are roots of $x^2 - 24x + q = 0$, and if a, b, c, d are in geometric progression then the value of the product pq is;
(a) 192 (b) 64 (c) 24 (d) 1024

19. A student measures the displacement x from the equilibrium of a stretched spring and reports it to be 100 μm with a 1% error. The spring constant K is known to be 500 Nm^{-1} with 0.5% error. The percentage of error in the estimate of the potential energy $V = \frac{1}{2}Kx^2$ is
(a) 0.8 % (b) 2.5 % (c) 1.5 % (d) 3.0 %

20. Two satellites are in the same geosynchronous orbit (assumed to be circular), but in diametrically opposite positions. One satellite descends into a lower circular orbit and catches up with the other after 8 complete orbits. Neglect the time of descent into lower orbit. If the radius of the geosynchronous orbit is 40000 km, the radius of the lower, faster orbit is about (using $7.5^{2/3} \approx 3.84$)
(a) $\approx 32400\ km$ (b) $\approx 34000\ km$ (c) $\approx 36000\ km$ (d) $\approx 38400\ km$

21. The ratio of the masses of the Earth and Mars is 10 and the ratio of the radii of the Earth and Mars is 2. If two persons jump with the same velocity and angle off the surface of each of the planets, the ratio of maximum height reached at Earth to that reached at Mars is
(a) $\frac{1}{5}$ (b) $\frac{2}{5}$
(c) $\frac{5}{2}$ (d) depends on the ratio of the masses of two people

22. A schematic Hertzsprung-Russel diagram for stars in the solar neighborhood is shown below.



The radius R of a star, its luminosity L and surface temperature T are related as $R \propto \frac{\sqrt{L}}{T^2}$

If for a star $\frac{R}{R_{sun}} = 20$ and T = 3000 K (using T_{sun} = 6000 K), then the star is a
(a) Blue Supergiant (b) Blue Giant (c) Red Supergiant (d) Red Giant

In questions 23 and 24 mark your answer as

(a) If statement I is true and statement II is true and also if the statement II is a correct explanation of statement I

(b) If statement I is true and statement II is true but the statement II is not a correct explanation of statement I

(c) If statement I is true but the statement II is false

(d) If statement I is false but statement II is true

23. Statement I: We cannot see what is near the centre of Galaxy
Statement II: There is a super – massive black hole at the centre of Galaxy

24. Statement I: Hydrogen gas is not found in large amount in the atmosphere of terrestrial planets.
Statement II: Speed of Hydrogen molecules was higher than the escape velocity on the terrestrial planets.

A – 2

ANY NUMBER OF OPTIONS 4, 3, 2 or 1 MAY BE CORRECT

MARKS WILL BE AWARDED ONLY IF ALL THE CORRECT OPTIONS ARE BUBBLED.

25. Electromagnetic waves also undergo Doppler effect just as sound waves. Use the expression of Doppler effect valid for small velocities (of source, or observer, they both give the same result for small velocities), replacing sound speed by speed of light c. A hydrogen atom moving along x axis with velocity v undergoes transition of electron from 1st excited level (n=2) to the ground state, emitting radiation which travels along x axis. This radiation is absorbed by another hydrogen atom at rest in its ground state causing it to get excited to n = 3 level. The value of v is approximately

(a) $5.55\times10^4\ km/\sec$ (b) $9.45\times10^4\ km/\sec$

(c) $0.315c$ (d) $0.185c$

26. A metal rod moving through a magnetic field may get induced e.m.f. (depending on the direction of the magnetic field and the orientation of the rod) due to the fact that

(a) current flowing through the rod leads to a force on the rod due to magnetic field

(b) magnetic field applies force on electrons in the rod

(c) changing magnetic field produces electric field

(d) electrons have a magnetic dipole moment which feels force due to magnetic field

27. If $\sin\left(\frac{\pi}{3}\right)=1-2\sin^2\theta$ then θ can be

(a) $\frac{\pi}{12}$ (b) $\frac{13\pi}{12}$

(c) $-\frac{11\pi}{12}$ (d) $\frac{25\pi}{12}$

28. Let the 2 x 2 matrix A = $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$, where a, b, c, d $\in$ R, with $A^2 = 0$. Then,

(a) A = 0 (b) a + d = 0 and det A = 0

(c) A^{-1} does not exist (d) a + d = 0 and b, c can be arbitrary

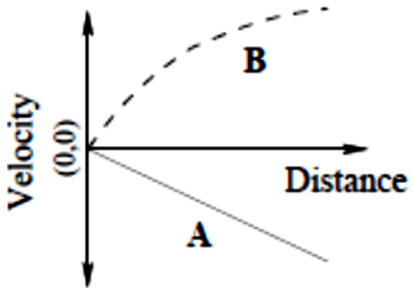
29. A light beam passes through a transparent medium of thickness L. After passing through the medium, the intensity of the light beam reduces because
(a) each photon loses some energy in the medium
(b) some photons get absorbed in the medium
(c) some photons get scattered by the medium in different directions
(d) some photons get reflected back as the light enters the transparent medium

30. Consider a pyramid with square base of length L and triangular faces as equilateral triangle. For this pyramid, the true statement(s) is / are
(a) The height of the pyramid is $\frac{L}{\sqrt{2}}$
(b) The area of the pyramid surface (including the base) is $\left(\sqrt{3}+1\right)L^2$.
(c) The volume of the pyramid is L^3.
(d) The angle between the base and the side is $tan^{-1}\sqrt{2}$.

31. Analysis of the spiral galaxy NGC 1357 spectra reveals a strong emission line at 6606 Å. Knowing the H_α emission line is at 6560 Å.
Use c = 3×10^5 km/s and Hubble's constant = 70 (km/s)/Mpc. Choose correct option(s)

(a) The velocity of NGC 1357 is about 2×10^3 km/s.
(b) NGC 1357 is an example of blue-shifted galaxy.
(c) The galaxy is at a distance of 30 Mpc from us.
(d) It is an old galaxy having little to no star formation regions.

32. The Hubble plot below depicts two alternate universe A (solid line) and B (dashed curve).



The quantity z determines the amount of redshift (negative z for blue shift) in the absorption and emission spectra of the galaxies. From the Hubble plot above, we can deduce that
(a) Both the universe A and B are contracting but at different rates.
(b) The galaxies in the universe A are blue shifted while those in B are red shifted.
(c) In the universe A, farther galaxies are approaching us at faster velocities than closer galaxies.
(d) The |z| – value is larger for the farther galaxies in B compared to those closer.

ROUGH WORK