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PREVIOUS YEAR PAPER · 2023

OLYMPIAD · STAGE I

NSEA

National Standard Examination in Astronomy

2023

Question paper, answer key and Zigyan solutions

60	216	120 min	41
Questions	Maximum marks	Time	Paper code

Question paper and official answer key: Indian Association of Physics Teachers (IAPT), NSEA 2023, paper code 41.
Solutions and notes: Zigyan. This booklet is not an IAPT publication.

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AIR 168	AIR 811
	99.95 percentile



Sulokya Bibhuty

3 YEARS CLASSROOM

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- Harshit Goyal — 4 Years Classroom
- Hardik Sharma — 3 Years Classroom
- Aarush Kumar — 1 Year Classroom

PHYSICS

- Sulokya Bibhuty — 3 Years Classroom
- Saksham Bishnoi — 4 Years Classroom

ASTRONOMY

- Sulokya Bibhuty — 3 Years Classroom

MATHEMATICS (IOQM)

- Priyanshi — 4 Years Classroom

Saksham Bishnoi qualified the Chemistry Olympiad twice and was selected for the Orientation-cum-Selection Camp at HBCSE, Mumbai.

16 selections	16 of 35	AIR 168
in JEE Advanced 2026	students of the batch selected	best JEE Advanced rank

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Given in the question paper

Physical constants you may need….

Magnitude of charge on electron $e = 1.60 \times 10^{-19}$ C	Faraday constant $= 96{,}500$ C / mol
Mass of electron $m_e = 9.11 \times 10^{-31}$ kg	Speed of light in free space $c = 3 \times 10^{8}$ ms^{-1}
Mass of proton $m_p = 1.67 \times 10^{-27}$ kg	Speed of sound in dry air at 0°C $v = 332$ ms^{-1}
Mass of neutron $m_n = 1.67 \times 10^{-27}$ 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 $h = 6.626 \times 10^{-34}$ Js
Universal gas constant $R = 8.31$ J / mol K	Rydberg constant $R = 1.097 \times 10^{7}$ m^{-1}
Boltzmann constant $k = 1.38 \times 10^{-23}$ J / K	Astronomical unit $= 1.50 \times 10^{11}$ m
Stefan's constant $\sigma = 5.67 \times 10^{-8}$ W / m^{2}K^4	Radius of Sun $R = 6.96 \times 10^{8}$ m
Avogadro's constant $A = 6.022 \times 10^{23}$ mol^{-1}	Mass of Sun $M = 2.0 \times 10^{30}$ kg

PART A-1 · ONE CORRECT OPTION

Q. 1 – 48 · +3 for a correct answer, –1 for a wrong one

1. Venus has an equatorial radius of 6052 km. The semi-major axis of its orbit around the Sun is 0.72 AU. The smallest diameter of the primary mirror/lens (objective) of an optical telescope to be used to just resolve the Venus disc during the transit of Venus is approximately

Physical constants you may need....

Astronomical unit = 1.50 × 10^{11} m

(A) 200 cm (B) 20 cm (C) 10 cm (D) 0.25 cm

Solution · Q1 **Answer: (D)**

During a transit, Venus lies between the Earth and the Sun. Its distance from the Earth is

$$d = (1 - 0.72) \times 1.50 \times 10^{11}\ \text{m} = 4.2 \times 10^{10}\ \text{m}$$

Angular diameter of the disc:

$$\theta = \frac{2 \times 6052 \times 10^{3}}{4.2 \times 10^{10}} \approx 2.88 \times 10^{-4}\ \text{rad}$$

For visible light, take

$$\lambda = 550\ \text{nm}$$

By the Rayleigh criterion,

$$D = \frac{1.22\lambda}{\theta}$$

$$\Rightarrow D \approx 2.3 \times 10^{-3}\ \text{m} = 0.23\ \text{cm}$$

The nearest option is 0.25 cm.

IAPT answer: (D) | **Zigyan answer:** (D)

2. The Earth's atmosphere is transparent across the most of the optical region and ..... region of the electromagnetic spectrum. Choose the correct option to fill the blank.

(A) ultraviolet (B) X-ray

(C) some portions of the radio wave (D) gamma-ray

Solution · Q2 **Answer: (C)**

The atmosphere has two main windows.

One is the optical window. The other is the radio window, which passes only some portions of the radio wave region.

IAPT answer: (C) | **Zigyan answer:** (C)

3. It is given that the pupil of the human eye is about 5 mm (in diameter). How many times more light-gathering power does a telescope with a primary mirror of diameter about 20 cm (8 inches) have than the human eye?

(A) 4 times (B) 16 times (C) 40 times (D) 1600 times

Solution · Q3 **Answer: (D)**

Light-gathering power is proportional to the area of the aperture.

For the telescope (P_1) and the eye (P_2),

$$\frac{P_1}{P_2} = \left(\frac{200\ \text{mm}}{5\ \text{mm}}\right)^2$$

$$\Rightarrow P_1 = 1600\ P_2$$

IAPT answer: (D) | **Zigyan answer:** (D)

4. An astronomer observes a spectral emission line from a galaxy at a wavelength of 600 nm. This same spectral line is measured in the laboratory using a stationary source and is seen to have wavelength 500 nm. The speed of the galaxy toward or away from Earth (in units of the speed of light c) is equal to

(A) 0.2 c moving away from Earth (B) 0.2 c moving toward Earth

(C) 0.9 c moving away from Earth (D) 1.0 c moving toward Earth

Solution · Q4 **Answer: (A)**

By the Doppler effect, for speeds small compared with that of light,

$$\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$$

$$\Rightarrow \frac{v}{c} = \frac{600 - 500}{500} = 0.2$$

The wavelength has increased (redshift), so the galaxy is moving away from the Earth.

IAPT answer: (A) | **Zigyan answer:** (A)

5. An astronomer observes that Polaris is 40 degrees above her northern horizon. What can you say about the longitude of her location from her observations?

(A) nothing
(B) that it is 40 degrees north
(C) that it is 50 degrees south
(D) that it is 40 degrees east

Solution · Q5 **Answer: (A)**

The altitude of Polaris above the northern horizon equals the latitude of the observer, here 40° N.

It tells nothing about her longitude.

IAPT answer: (A) | **Zigyan answer:** (A)

6. The spectrum of a cloud of cool gas seen against a bright background black body would show

(A) bright lines (emission spectrum) against a continuum spectral emission background
(B) a continuous spectrum
(C) dark lines (absorption lines) against a continuum emission background
(D) either bright or dark lines, depending on distance, against a continuum emission background

Solution · Q6 **Answer: (C)**

By Kirchhoff's laws of spectroscopy, a cool gas in front of a hotter continuous source absorbs its own characteristic wavelengths.

So dark absorption lines appear on the continuous background.

IAPT answer: (C) | **Zigyan answer:** (C)

7. If a star has a parallax of one-eighth of a second of arc, its distance from the earth is

(A) 2,06,265 astronomical units
(B) eight light years
(C) one-eighth parsec
(D) eight parsec

Solution · Q7 **Answer: (D)**

The distance in parsec is the reciprocal of the parallax in seconds of arc.

$$d = \frac{1}{p}$$

$$p = 0.125''$$

$$\Rightarrow d = 8 \text{ pc}$$

IAPT answer: (D) | **Zigyan answer:** (D)

8. The elemental composition of the Sun, by mass, is about

(A) 50 % metals, 50 % hydrogen
(B) 71 % hydrogen, 27 % helium, 2 % others
(C) 75 % helium, 20 % hydrogen, 5 % others
(D) 75 % carbon, 25 % helium

Solution · Q8 **Answer: (B)**

By mass, the Sun is mainly hydrogen and helium.

It is about 71 % hydrogen, 27 % helium and 2 % heavier elements.

IAPT answer: (B) | **Zigyan answer:** (B)

9. Which of the following planets has essentially no atmosphere?

(A) Venus (B) Mercury (C) Jupiter (D) Mars

Solution · Q9 **Answer: (B)**

Mercury is small, with a low escape speed, and its sunlit side is very hot.

It cannot hold an appreciable atmosphere and has only an extremely thin exosphere.

IAPT answer: (B) | **Zigyan answer:** (B)

10. Sunspots are

(A) relatively cool compared to the photosphere

(B) related to convection cells

(C) related to the Sun's electric field

(D) cyclonic storms similar to Jupiter's great red spot

Solution · Q10 **Answer: (A)**

Strong magnetic fields in sunspots suppress convection, so less heat reaches the surface there.

Sunspots are therefore cooler than the surrounding photosphere and look dark against it.

IAPT answer: (A) | **Zigyan answer:** (A)

11. A planet moves fastest in its orbit

(A) when it is in opposition (B) when it is closest to the Sun

(C) the greater its mass (D) when it is farthest from the Sun

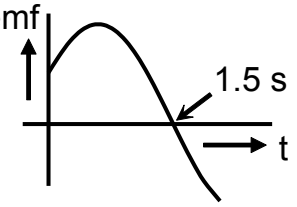
Solution · Q11 **Answer: (B)**

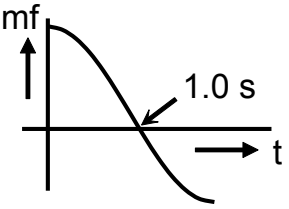
By Kepler's second law, the line joining the Sun to the planet sweeps equal areas in equal times.

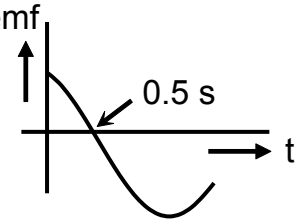
So the planet moves fastest when it is closest to the Sun (perihelion).

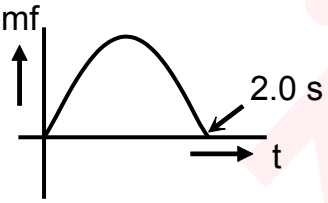
IAPT answer: (B) | **Zigyan answer:** (B)

12. A square loop of side 10 cm and resistance 0.5 Ω is placed vertically in the east-west (x-z) plane. A uniform magnetic field of strength B = 0.1T is set up across the plane of the coil in the north-south direction. The coil is rotating about a vertical axis $\left(\vec{\omega} \parallel \hat{k}\right)$ through its center at the rate of one rotation per 4 second. At time t = 0, the plane of the coil makes an angle θ = +45° with the east-west (x-z) plane. The correct schematic diagram giving the emf induced in the coil is

(A)


(B)


(C)


(D)


Solution · Q12 **Answer: (A)**

The coil makes one rotation in 4 s.

$$\omega = \frac{2\pi}{4} = \frac{\pi}{2}\ \text{rad / s}$$

The magnetic field is normal to the x-z plane. The area vector is taken so that the initial emf is positive, as in the graphs. Its angle with the field is

$$\alpha = \omega t + \frac{\pi}{4}$$

$$\Phi = BA\cos\alpha$$

$$e = -\frac{d\Phi}{dt} = BA\omega\sin\left(\omega t + \frac{\pi}{4}\right)$$

At the start, the emf is not zero and is still increasing. It first becomes zero when

$$\omega t + \frac{\pi}{4} = \pi$$

$$\Rightarrow t = 1.5\ \text{s}$$

IAPT answer: (A) | **Zigyan answer:** (A)

13. In 1912 Henrietta Leavitt making observations of Cepheid variable stars in the Magellanic clouds discovered the period luminosity relation – fainter stars have shorter periods. The relation between the apparent magnitude m (the measured magnitude of a star situated at its actual distance D pc) and its absolute magnitude M (its magnitude if located at a distance of 10 pc) is given by the magnitude distance relation $m - M = 5 \log D - 5$. Here D is the distance in parsec. The distance from Milky Way to the Andromeda galaxy is 765 kpc. The observed period luminosity relation determined by observations in the K band for Cepheid variables in the Andromeda galaxy is $m_K = -3.26 (\log P - 1) + 18.73$ with slope – 3.26 and zero-point 18.73. For Cepheids in the Milky Way $M_K = -3.26 (\log P - 1) + c$ where c is approximately

(A) – 5.69 (B) 5.67 (C) +18.73 (D) – 10.67

Solution · Q13 **Answer: (A)**

The same period luminosity relation holds for Cepheids in both galaxies.

For Andromeda,

$$D = 765 \text{ kpc} = 7.65 \times 10^5 \text{ pc}$$

$$M_K = m_K - 5 \log D + 5$$

$$\Rightarrow c = 18.73 - 5 \log (7.65 \times 10^5) + 5$$

$$\Rightarrow c = 18.73 - 29.42 + 5$$

$$\Rightarrow c \approx -5.69$$

IAPT answer: (A) | **Zigyan answer:** (A)

14. A Red Giant star of mass $M_{\text{Red Giant}}$ and a White Dwarf star of mass $m_{\text{White Dwarf}}$ form a binary system and are rotating in circular orbits around their common centre of mass with a period of one year. The White Dwarf is orbiting just within the photosphere of the Red Giant star. The Red Giant has a radius of 3.6 AU. An estimate for the mass of the Red Giant star in solar mass units is (note that $m_{\text{White Dwarf}} \ll M_{\text{Red Giant}}$)

(A) 188 (B) 94 (C) 47 (D) 13

Solution · Q14 **Answer: (C)**

The White Dwarf moves just inside the photosphere, so the separation of the stars is

$$a \approx 3.6 \text{ AU}$$

The White Dwarf's mass is negligible. By Kepler's third law, with mass in solar units, a in AU and T in years,

$$M = a^3/T^2$$

$$\Rightarrow M = (3.6)^3/1^2$$

$$\Rightarrow M = 46.7 \approx 47$$

IAPT answer: (C) | **Zigyan answer:** (C)

15. In spectroscopy doublet lines are closely spaced spectral lines that arise from transitions from a common fundamental state to states which differ only in their total angular momentum value. If a source of light is moving away from us the light from the source will appear shifted to the longer wavelength (red) side of the spectrum. The shift is quantified by the redshift $z = \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$, where λ is the observed wavelength of the spectral line when the emitting source is at rest with respect to the observer and $\Delta\lambda$ is the observed shift in the wavelength. Hubble observed that spectral lines of galaxies not very close to us are redshifted. A galaxy is showing a redshift of z = 0.005. The observed wavelength separation, in nanometre, of the sodium doublet at 589 and 589.6 nm and of the potassium doublet at 766.5 and 769.9 nm in the spectrum of the galaxy are respectively

(A) 0.603, 3.417 (B) 0.003, 0.017 (C) 38.33, 29.45 (D) 38.33, 38.5

Solution · Q15 **Answer: (A)**

Observed wavelength:

$$\lambda' = \lambda(1 + z)$$

So the observed separation is

$$\Delta\lambda' = (1 + z)(\lambda_2 - \lambda_1)$$

Sodium doublet:

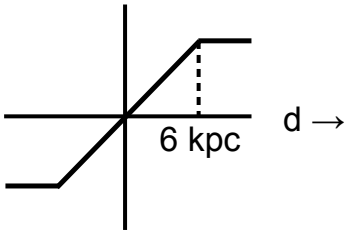
$$\Delta\lambda' = 1.005 \times 0.6 = 0.603 \text{ nm}$$

Potassium doublet:

$$\Delta\lambda' = 1.005 \times 3.4 = 3.417 \text{ nm}$$

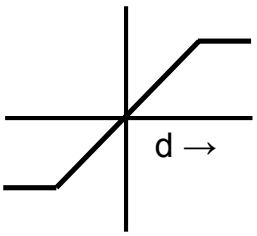
IAPT answer: (A) | **Zigyan answer:** (A)

16. The rotation curve of a spiral galaxy gives the 'instantaneous' local mean tangential velocity in the plane of the galaxy of stars/gas clouds in the galaxy lying along a line through the centre of the galaxy, with respect to the distant quasars as observed from the centre of the galaxy. The following is a schematic diagram of the rotation curve of a particular spiral galaxy.

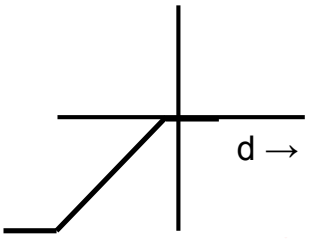


As measured from a star orbiting at a distance r = 8 kilo parsec from the centre, which one of the following diagrams gives a schematic representation of the mean tangential velocity v(d) with which objects at various distances d from the star, along the line joining the star to the centre of the galaxy, will appear to move with respect to the distant quasars?

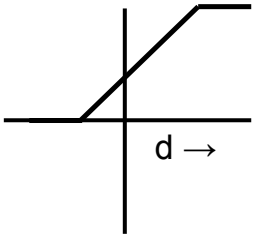
(A)



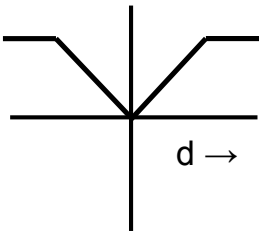
(B)



(C)



(D)



Solution · Q16 **Answer: (B)**

The star is on the flat part of the curve; let its speed be v_0. Take d positive away from the centre. For a point at position x measured from the centre,

$$x = 8 \text{ kpc} + d$$

Velocity seen from the star:

$$v(d) = v(x) - v_0$$

Outer flat part:

$$d > -2 \text{ kpc}$$

$$\Rightarrow v(d) = 0$$

Rising part:

$$-14 \text{ kpc} < d < -2 \text{ kpc}$$

Here v(d) rises uniformly from $-2v_0$ to zero.

Far flat part:

$$d < -14 \text{ kpc}$$

$$\Rightarrow v(d) = -2v_0$$

This is graph (B).

IAPT answer: (B) | **Zigyan answer:** (B)

17. The relation R on Z the set of integers, defined by $(x, y) \in R$ if and only if $xy \neq 0$ is

(A) Reflexive, symmetric and transitive
(B) Reflexive, symmetric but not transitive
(C) Symmetric, transitive but not reflexive
(D) Transitive, reflexive but not symmetric

Solution · Q17 **Answer: (C)**

Not reflexive, because for the integer zero,

$$0 \times 0 = 0$$

$\Rightarrow (0, 0) \notin R$

Symmetric:

$xy \neq 0 \Rightarrow yx \neq 0$

Transitive:

$xy \neq 0, yz \neq 0$

$\Rightarrow x \neq 0, z \neq 0$

$\Rightarrow xz \neq 0$

$\therefore$ R is symmetric and transitive but not reflexive.

IAPT answer: (C) | **Zigyan answer:** (C)

18. A is a 3 × 3 non-singular matrix such that $A^4 = 4A$. What is the determinant of A?

(A) 0 (B) 4 (C) 16 (D) 64

Solution · Q18 **Answer: (B)**

Taking determinants of both sides,

$$|A^4| = |4A|$$

$$\Rightarrow |A|^4 = 4^3|A|$$

A is non-singular, so cancel one determinant factor.

$$\Rightarrow |A|^3 = 4^3$$

For a real matrix,

$$\Rightarrow |A| = 4$$

IAPT answer: (B) | **Zigyan answer:** (B)

19. The number of real values of θ that satisfy the equation $\sin^2\theta - 5\sin\theta + 6 = 0$ is

(A) 0 (B) 1 (C) 2 (D) 3

Solution · Q19 **Answer: (A)**

Factorising,

$$(\sin\theta - 2)(\sin\theta - 3) = 0$$

$$\Rightarrow \sin\theta = 2 \text{ or } \sin\theta = 3$$

But for every real angle,

$$-1 \le \sin\theta \le 1$$

$\therefore$ no real value of θ exists.

IAPT answer: (A) | **Zigyan answer:** (A)

20. If z is a complex number such that $\frac{z-2}{z+2} = i$, the value of |z| is

(A) 0 (B) 1 (C) 2 (D) 3

Solution · Q20 **Answer: (C)**

$$z - 2 = i(z + 2)$$

$$\Rightarrow z(1 - i) = 2(1 + i)$$

$$\Rightarrow z = \frac{2(1+i)}{1-i} = 2i$$

$$\therefore |z| = 2$$

IAPT answer: (C) | **Zigyan answer:** (C)

21. The number of positive divisors of 202300 is

(A) 8 (B) 18 (C) 26 (D) 54

Solution · Q21 **Answer: (D)**

Prime factorisation:

$$202300 = 2^2 \times 5^2 \times 7 \times 17^2$$

Number of positive divisors:

$$(2 + 1)(2 + 1)(1 + 1)(2 + 1) = 54$$

IAPT answer: (D) | **Zigyan answer:** (D)

22. For what values of a and b is the following function continuous at x = 2?

$$f(x) = \begin{cases} ax^2 + bx + 1 & \text{if } x \geq 2 \\ 3 & \text{if } x = 2 \\ bx^2 - ax - 11 & \text{if } x < 2 \end{cases}$$

(A) a = 1, b = 9 (B) a = 2, b = 12 (C) a = −1, b = 3 (D) a = −3, b = −3

Solution · Q22 **As per Zigyan: (C)**

The first rule is used to the right of the point; at the point itself the value is 3.

Right hand limit equals the value:

$$4a + 2b + 1 = 3$$

Left hand limit equals the value:

$$4b - 2a - 11 = 3$$

Solving the two equations,

$$a = -1, b = 3$$

Check: With these values the first quadratic is $-x^2 + 3x + 1$ and the last is $3x^2 + x - 11$. At the point two, each gives 3.

IAPT answer: (C) | **Zigyan answer:** (C)

23. The value of the integral $\int_0^{\pi} |\cos 2x| dx$ is

(A) 0 (B) 1 (C) 2 (D) 3

Solution · Q23 **Answer: (C)**

The integrand has period π/2 and is symmetric about the middle of each period. Hence

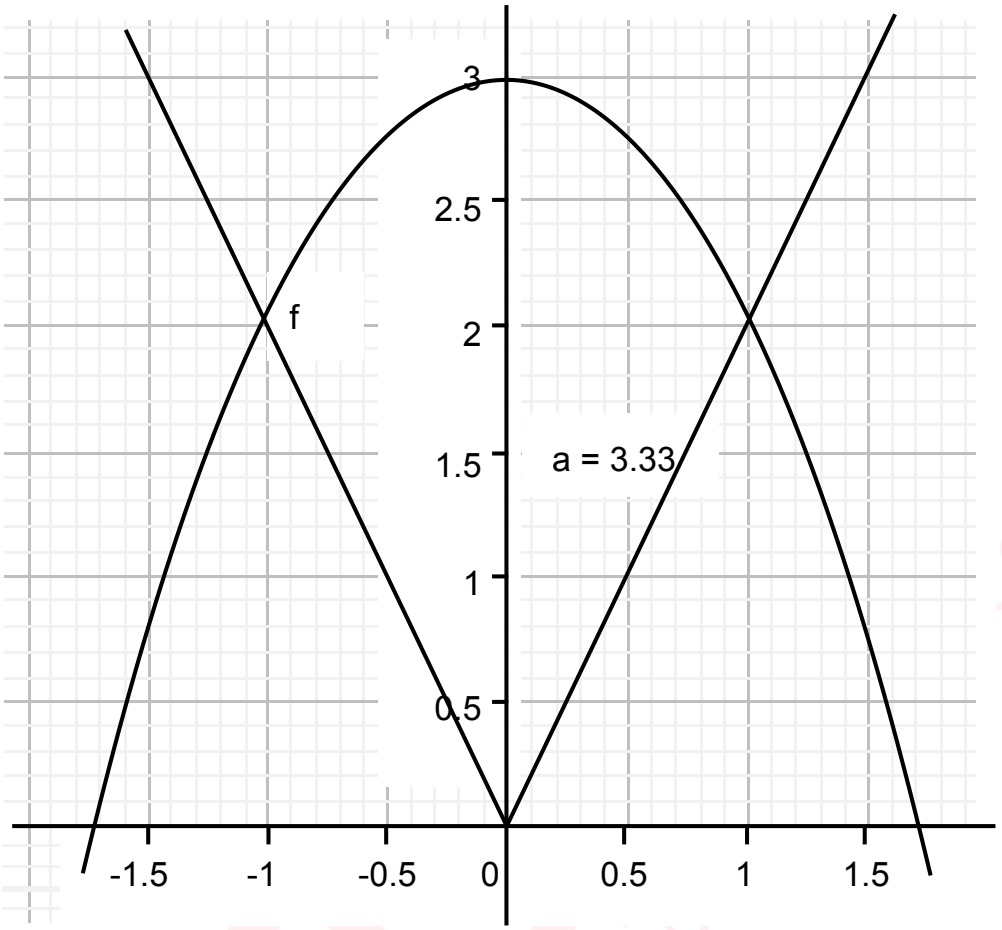
$$I = 4\int_0^{\pi/4} \cos 2x dx$$

$$\Rightarrow I = 2[\sin 2x]_0^{\pi/4}$$

$$\Rightarrow I = 2$$

IAPT answer: (C) | **Zigyan answer:** (C)

24. The area bounded by $y = 3 - x^2$ and $y = 2|x|$ is



(A) $\frac{5}{3}$ (B) $\frac{8}{3}$

(C) $\frac{10}{3}$ (D) $\frac{16}{3}$

Solution · Q24 **Answer: (C)**

The curves meet where

$$3 - x^2 = 2|x|$$

$$\Rightarrow |x| = 1$$

The region is symmetric about the y-axis, so

$$A = 2\int_0^1 (3 - x^2 - 2x)\,dx$$

$$\Rightarrow A = 2(3 - 1/3 - 1)$$

$$\Rightarrow A = \frac{10}{3}$$

IAPT answer: (C) | **Zigyan answer:** (C)

25. Two unbiased dice are thrown simultaneously. What is the probability that both the dice show prime numbers?

(A) $\frac{7}{36}$ (B) $\frac{1}{12}$

(C) $\frac{1}{6}$ (D) $\frac{1}{4}$

Solution · Q25 **Answer: (D)**

The primes on a die are 2, 3 and 5.

For one die,

$$P = \frac{3}{6} = \frac{1}{2}$$

The two dice are independent, so for both,

$$P = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$

IAPT answer: (D) | **Zigyan answer:** (D)

26. The differential equation $\frac{dy}{dx} = \frac{y}{x}$ represents

(A) a family of concurrent straight lines

(B) a family of straight lines passing through (1, 1)

(C) a family of straight lines parallel to X - axis

(D) a family of straight lines parallel to Y - axis

Solution · Q26 **Answer: (A)**

$$\frac{dy}{y} = \frac{dx}{x}$$

$$\Rightarrow \ln y = \ln x + \ln c$$

$$\Rightarrow y = cx$$

Every line of this family passes through the origin, so the lines are concurrent.

IAPT answer: (A) | **Zigyan answer:** (A)

27. The volume of a magical right circular cylinder of fixed height changes at a constant rate. Initially, the base radius was 3 units and it changed to 6 units in 3 seconds. What is the radius of the base at time t ?

(A) $3\sqrt{\pi t + 1}$ (B) $3\sqrt{t + 1}$

(C) $3\sqrt{t + \pi}$ (D) $3\sqrt{\pi t + \pi}$

Solution · Q27 **Answer: (B)**

The height h is fixed.

$$V = \pi r^2 h$$

V changes at a constant rate, so r^2 is linear in time.

$$r^2 = at + b$$

From the initial radius,

$$b = 9$$

From the radius after 3 seconds,

$$36 = 3a + 9$$

$$\Rightarrow a = 9$$

$$\Rightarrow r = 3\sqrt{t+1}$$

IAPT answer: (B) | **Zigyan answer:** (B)

28. The Lane Emden equation $\frac{1}{x^2}\frac{d}{dx}\left(x^2\frac{dy}{dx}\right) + y^n = 0$, is the governing equation for a crude model for a star. Here the star is treated as a sphere of gas with a polytropic equation of state. The differential equation admits exact solutions for polytropic index n = 0, 1 and 5 as $y(x) = 1 - \frac{x^2}{6}$, $\frac{\sin x}{x}$ and $\frac{1}{\sqrt{1+\frac{x^2}{3}}}$. The value of $x = x_0$ is such that $y(x_0) = 0$ defines the surface of the star. The quantity $R = \frac{x_0^3}{3\left|-x^2\frac{dy}{dx}\right|_{x_0}}$ gives $\frac{\rho_{central}}{\rho_{average}}$ the ratio of the central density to the average density for the model star. $\left|-x^2\frac{dy}{dx}\right|_{x_0}$ means the value of $-x^2\frac{dy}{dx}$ evaluated at x_0. The value of R for n = 0, 1 are

(A) $1, \frac{\pi}{3}$ (B) $\sqrt{6}, \frac{\pi}{3}$

(C) $\infty, \frac{\pi^2}{3}$ (D) $1, \frac{\pi^2}{3}$

Solution · Q28 **Answer: (D)**

First model:

$$n = 0,\ y(x_0) = 0$$

$$\Rightarrow x_0 = \sqrt{6}$$

$$-x^2\frac{dy}{dx} = \frac{x^3}{3}$$

$$\Rightarrow R = \frac{x_0^3}{3\left(\frac{x_0^3}{3}\right)} = 1$$

Second model:

$$n = 1,\ \sin x_0 = 0$$

$$\Rightarrow x_0 = \pi$$

$$-x^2\frac{dy}{dx} = \sin x - x\cos x$$

At the surface this expression equals π.

$$\Rightarrow R = \frac{\pi^3}{3\pi} = \frac{\pi^2}{3}$$

IAPT answer: (D) | **Zigyan answer:** (D)

29. The logistic map iteratively maps x_{n+1} to x_n ($n = 0, 1, 2, \ldots\ldots\ldots\ldots\ldots$) through the equation $x_{n+1} = \lambda x_n(1 - x_n)$. Consider the two different initial values: $x_0 = 0.25$ and $x'_0 = x_0 + 0.01 = 0.26$. For $\lambda = 3.25$, the difference between the second iterates $(x_2' - x_2)$ is approximately

(A) 0.01 (B) – 0.01 (C) 0.02 (D) 0.001

Solution · Q29 **Answer: (B)**

$$x_1 = 3.25 \times 0.25 \times 0.75 = 0.6094$$

$$\Rightarrow x_2 = 3.25 \times 0.6094 \times 0.3906 = 0.7736$$

$$x_1' = 3.25 \times 0.26 \times 0.74 = 0.6253$$

$$\Rightarrow x_2' = 3.25 \times 0.6253 \times 0.3747 = 0.7615$$

$$\therefore x_2' - x_2 = 0.7615 - 0.7736 \approx -0.01$$

IAPT answer: (B) | **Zigyan answer:** (B)

30. In a class of 40 students 25 have opted Hindi as second language (event A). 35 students got first class (event B) in the examinations of which 20 had taken Hindi as second language. It is found that a student picked at random has secured first class. The probability P(A/B) that this student has taken Hindi as second language is

(A) $\frac{4}{7}$ (B) $\frac{5}{8}$
(C) $\frac{7}{8}$ (D) $\frac{1}{2}$

Solution · Q30 **Answer: (A)**

Event B has 35 students, and 20 of them are also in A.

$$P(A/B) = \frac{n(A \cap B)}{n(B)}$$

$$\Rightarrow P(A/B) = \frac{20}{35} = \frac{4}{7}$$

IAPT answer: (A) | **Zigyan answer:** (A)

31. When a line segment/square/cube of side length L is measured using a line segment/square/cube of side length l, the number N of line segments/squares/cubes covering the original line segment/square/cube is given by $\left(\frac{L}{l}\right)$, $\left(\frac{L}{l}\right)^2$, $\left(\frac{L}{l}\right)^3$ respectively. Define the dimension of an object as $D = [-\log(N)/\log(l)]$ as $l \to 0$. The n = 0, n = 1 and n = 2 steps of iteration of the process of obtaining the fractal curve called a Koch curve, of stretching and bending the middle one third of a line segment (of length L) into a triangle shape of side length L/3 is shown in the figure; in the second (n = 2) iteration each of the 4 line segments of length L/3 will have their middle one third stretched and bend into triangle shapes of side $l = L/(3 \times 3)$. After n iterations the total number N of line segments of length $l = L/3^n$ making up the figure will be 4^n. The dimension D of the Koch curve, obtained as $n \to \infty$ (i.e. as $l \to 0$) is



(A) $\frac{\log 4}{\log 3}$

(B) $\log\left(\frac{4}{3}\right)$

(C) 1

(D) 1.3

Solution · Q31 **Answer: (A)**

After n iterations,

$$N = 4^n,\ l = L/3^n$$

$$D = \lim_{n \to \infty} \frac{n\log 4}{n\log 3 - \log L}$$

The fixed term log L becomes negligible for very large n.

$$\Rightarrow D = \frac{\log 4}{\log 3}$$

IAPT answer: (A) | **Zigyan answer:** (A)

32. Consider the two sets G = {1, i, −i, −1} and G′ = {$R_{\pi/2}$, R_{π}, $R_{3\pi/2}$, $R_{2\pi}$}, where R_θ stands for rotation of a square by angle θ in the anticlockwise direction about an axis through its centre and perpendicular to its plane. If product of two elements of G is taken by complex multiplication and the product of two elements of G' are taken as $R_\theta R_\phi = R_{\theta+\phi}$, then, under which of the following mappings between G and G' do the product relations hold unchanged?

(A) $\begin{pmatrix} g_1 \to g_1' \\ g_2 \to g_2' \\ g_3 \to g_3' \\ g_4 \to g_4' \end{pmatrix}$

(B) $\begin{pmatrix} g_1 \to g_4' \\ g_2 \to g_1' \\ g_3 \to g_3' \\ g_4 \to g_2' \end{pmatrix}$

(C) $\begin{pmatrix} g_1 \to g_3' \\ g_2 \to g_4' \\ g_3 \to g_1' \\ g_4 \to g_2' \end{pmatrix}$

(D) $\begin{pmatrix} g_1 \to g_2' \\ g_2 \to g_3' \\ g_3 \to g_4' \\ g_4 \to g_1' \end{pmatrix}$

Solution · Q32 **Answer: (B)**

Take g_1 to g_4 in the printed order of G, and g_1' to g_4' in the order of G′.

Identity must go to identity:

$1 \rightarrow R_{2\pi}$

The element of order two must go to the element of order two:

$-1 \rightarrow R_{\pi}$

Send i to the quarter turn; –i, its third power, goes to the three-quarter turn.

$i \rightarrow R_{\pi/2}$, $-i \rightarrow R_{3\pi/2}$

Hence the mapping is:

$g_1 \rightarrow g_4'$, $g_2 \rightarrow g_1'$

$g_3 \rightarrow g_3'$, $g_4 \rightarrow g_2'$

IAPT answer: (B) | **Zigyan answer:** (B)

33. The objective of a reflecting telescope is a concave mirror of focal length 750 mm. To double the magnification, a concave lens of focal length 20 mm is placed near the focus of the primary mirror. What should be the position of the eyepiece focus from the concave lens?

(A) 10 mm away from mirror
(B) 10 mm towards mirror
(C) 20 mm away from mirror
(D) 20 mm towards mirror

Solution · Q33 **Answer: (C)**

The converging beam from the mirror forms a virtual object for the concave lens.

To double the magnification,

$$m = \frac{v}{u} = 2$$

Distances along the reflected light are taken as positive.

$$\frac{1}{2u} - \frac{1}{u} = -\frac{1}{20}$$

$$\Rightarrow u = 10 \text{ mm}$$

$$\Rightarrow v = 20 \text{ mm}$$

The new image is 20 mm from the lens, on the side away from the mirror. The eyepiece focus must be at this image.

IAPT answer: (C) | **Zigyan answer:** (C)

34. On the basis of Bohr Theory of atomic structure, the total energy required to remove both electrons from the helium atom in its ground state is 79 eV. How much energy is required to ionize helium i,e to remove the first electron?

(A) 79.0 eV (B) 54.4 eV (C) 39.5 eV (D) 24.6 eV

Solution · Q34 **Answer: (D)**

After the first electron leaves, He^+ is hydrogen-like. Energy to remove the second electron:

$$E_2 = 13.6 \times 2^2 \text{ eV} = 54.4 \text{ eV}$$

$$\Rightarrow E_1 = 79 - 54.4$$

$$\Rightarrow E_1 = 24.6 \text{ eV}$$

IAPT answer: (D) | **Zigyan answer:** (D)

35. Five positive charges, each of magnitude q, are arranged symmetrically on the circumference of a circle of radius r. The magnitude of the electric field E at the center of the circle is

(A) Zero

(B) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

(C) $\frac{1}{\pi\varepsilon_0}\frac{q}{r^2}$

(D) $\frac{5}{4\pi\varepsilon_0}\frac{q}{r^2}$

Solution · Q35 **Answer: (A)**

Adjacent charges subtend 72° at the centre.

The five fields there are equal in magnitude, with directions 72° apart. Added head to tail, they close into a regular pentagon.

$$\therefore E = 0$$

IAPT answer: (A) | **Zigyan answer:** (A)

36. A particle is constrained to move along a circle of radius R = 1.0 m. At a certain instant of time, the speed of the particle is 1.0 m/s and the speed is increasing at the rate of 1.0 m/s^2. The angle (in radian) between the velocity and the acceleration vectors of the particle is

(A) Zero

(B) $\frac{\pi}{6}$

(C) $\frac{\pi}{4}$

(D) $\frac{\pi}{2}$

Solution · Q36 **Answer: (C)**

Centripetal acceleration:

$$a_c = \frac{v^2}{R}$$

$$\Rightarrow a_c = 1.0\ \text{m/s}^2$$

Tangential acceleration, along the velocity:

$$a_t = 1.0\ \text{m/s}^2$$

$$\tan\theta = \frac{a_c}{a_t} = 1$$

$$\Rightarrow \theta = \pi/4$$

IAPT answer: (C) | **Zigyan answer:** (C)

37. A certain amount of helium gas is expanded adiabatically to one and half times of its initial volume. If the initial temperature is 27°C, the final temperature of the gas will be

(A) +3.6°C (B) − 5.8°C (C) − 10.9°C (D) − 44.1°C

Solution · Q37 **Answer: (D)**

Helium is monatomic. For an adiabatic change,

$$\gamma = 5/3$$

$$T_2V_2^{\gamma-1} = T_1V_1^{\gamma-1}$$

$$T_1 = 300\ \text{K},\ V_2 = 1.5V_1$$

$$\Rightarrow T_2 = 300 \times (2/3)^{2/3}$$

$$\Rightarrow T_2 \approx 228.9\ \text{K}$$

On the Celsius scale:

$$\therefore t_2 = 228.9 - 273 \approx -44.1\ ^\circ\text{C}$$

IAPT answer: (D) | **Zigyan answer:** (D)

38. Absorbing a neutron, $^{235}_{92}$U undergoes fission producing two fragments in the intermediate atomic mass range namely $^{89}_{36}$Kr and $^{144}_{56}$Ba along with three neutrons and energy. By what factor is the size of the so produced $^{144}_{56}$Ba nucleus smaller than that of the $^{235}_{92}$U nucleus?

(A) 0.61 (B) 0.72 (C) 0.78 (D) 0.85

Solution · Q38 **Answer: (D)**

The radius of a nucleus of mass number A is

$$R = R_0 A^{1/3}$$

$$\frac{R_{Ba}}{R_U} = \left(\frac{144}{235}\right)^{1/3}$$

$$\Rightarrow \frac{R_{Ba}}{R_U} \approx 0.85$$

IAPT answer: (D) | **Zigyan answer:** (D)

39. A small wooden block of mass 2 kg is dropped from a height h = 40 cm on a vertical spring of force constant k = 1960 N/m. The maximum compression of the spring is

Physical constants you may need....

Acceleration due to gravity g = 9.81 ms^{-2}

(A) 0.1 cm (B) 1.0 cm (C) 10.0 cm (D) 23.0 cm

Solution · Q39 **Answer: (C)**

At the maximum compression x the block is momentarily at rest. By conservation of energy,

$$mg(h + x) = kx^2/2$$

$$2 \times 9.81 \times (0.40 + x) = 980x^2$$

$$\Rightarrow 980x^2 - 19.62x - 7.848 = 0$$

Taking the positive root:

$$\Rightarrow x \approx 0.100\ \text{m} = 10.0\ \text{cm}$$

IAPT answer: (C) | **Zigyan answer:** (C)

40. The intensity level of a particular sound source is increased by 10 dB, the corresponding change in the amplitude of the sound wave is

(A) $\sqrt{10}$ times
(B) $10\sqrt{10}$ times
(C) 10 times
(D) 100 times

Solution · Q40 **Answer: (A)**

For the change in intensity level:

$$10 \log(I_2/I_1) = 10$$

$$\Rightarrow I_2/I_1 = 10$$

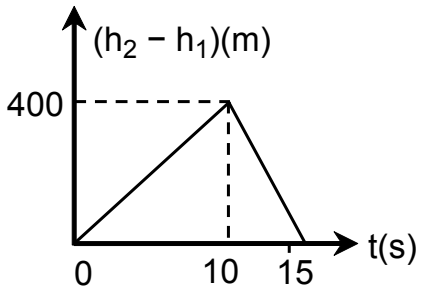
Intensity is proportional to the square of the amplitude a.

$$\therefore \frac{a_2}{a_1} = \sqrt{10}$$

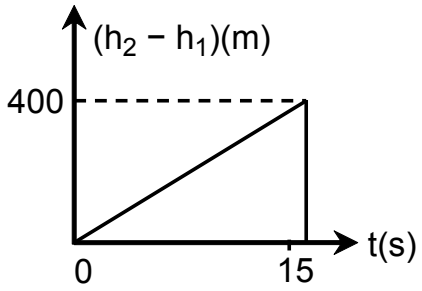
IAPT answer: (A) | **Zigyan answer:** (A)

41. Two stones of equal mass are thrown vertically up simultaneously from the edge of a cliff 400 m high with initial speeds of $v_1 = 10\ ms^{-1}$ and $v_2 = 50\ ms^{-1}$ respectively. Which of the following graphs best represents the time variation of relative position [height $(h_2 - h_1)$] of the second stone with respect to the first? (Assume that the stones are not obstructed at the cliff while going down and do not rebound after hitting the ground. Also ignore the small horizontal separation between the stones as well as air resistance, take $g = 10\ ms^{-2}$)

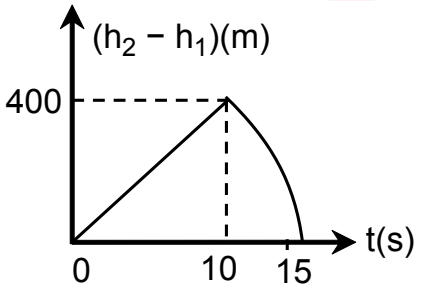
(A)



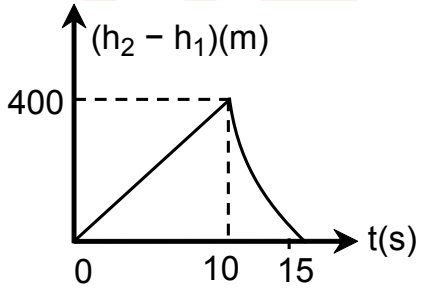
(B)



(C)



(D)



Solution · Q41 **Answer: (C)**

The first stone reaches the ground when:

$$400 + 10t - 5t^2 = 0$$

$$\Rightarrow t = 10\ s$$

Until then both stones are in the air.

$$h_2 - h_1 = (50 - 10)t = 40t$$

This is a straight line rising to 400 m at 10 s.

Afterwards the first stone stays on the ground.

$$h_2 - h_1 = 400 + 50t - 5t^2$$

This parabola bends downwards and falls to zero when the second stone lands, at about 15.2 s.

IAPT answer: (C) | **Zigyan answer:** (C)

42. A crow is sitting on a standard electric power line. The crow is not affected by the potential drop across its feet because

(A) it has non-conducting pads at the bottom of its feet

(B) the potential drop is too small for any significant current to flow through its body

(C) the crow is carefully sitting on the neutral line

(D) none of the above

Solution · Q42 **Answer: (B)**

Both feet are on the same wire, a very short distance apart. The resistance of that piece of wire is very small, so the potential drop between the feet is very small.

The body of the crow has a far larger resistance, so only a negligible current flows through it.

IAPT answer: (B) | **Zigyan answer:** (B)

43. Standing waves have been produced in a 51 cm long, open end organ pipe with just one node within the pipe. The wavelength of the sound wave, which forms a standing wave in the same organ pipe such that there are three nodes within the pipe, is

(A) 68 cm (B) 51 cm (C) 34 cm (D) 20.4 cm

Solution · Q43 **Answer: (C)**

The pipe is open at both ends, so each end is an antinode. With n nodes inside a pipe of length L,

$$L = \frac{n\lambda}{2}$$

For three nodes:

$$51 = \frac{3\lambda}{2}$$

$$\Rightarrow \lambda = 34 \text{ cm}$$

IAPT answer: (C) | **Zigyan answer:** (C)

44. For the air-glass interface if the Brewster angle (polarizing angle) is ϕ_P , then the critical angle (i_c) for the glass-air interface is expressed as

(A) $\sin^{-1}(\tan \phi_P)$ (B) $\cos^{-1}(\tan \phi_P)$

(C) $\sin^{-1}(\cot \phi_P)$ (D) $\cos^{-1}(\cot \phi_P)$

Solution · Q44 **Answer: (C)**

For the refractive index μ of glass, by Brewster's law,

$$\mu = \tan \phi_P$$

For the critical angle from glass to air:

$$\sin i_c = 1/\mu$$

$$\Rightarrow \sin i_c = \cot \phi_P$$

$$\therefore i_c = \sin^{-1}(\cot \phi_P)$$

IAPT answer: (C) | **Zigyan answer:** (C)

45. A gas in equilibrium attains a state of equipartition, wherein every active degree of freedom of every particle has on the average the same energy. In particular, the average translational kinetic energy will be the same for every particle; it will be equal to $\frac{3}{2}kT$ where, k is the Boltzmann constant and T is the temperature of the gas in kelvin. Consider air at 300 kelvin. If the root mean square velocity of nitrogen molecules is v_{rms} m/s, the magnitude of the mean velocity and the root mean square velocity of oxygen molecules are respectively

(A) $\left(0, \frac{v_{rms}}{2\sqrt{3}}\right)$

(B) $(0, 0.94v_{rms})$

(C) $\left(\frac{3}{2}v_{rms}, 1.07v_{rms}\right)$

(D) $(0, 0.875\ v_{rms})$

Solution · Q45 **Answer: (B)**

The molecules move randomly in all directions, so the mean velocity of oxygen molecules is zero.

At a given temperature, for molar mass M,

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

Comparing oxygen with nitrogen:

$$\frac{v_{rms,\ oxygen}}{v_{rms}} = \sqrt{\frac{28}{32}} \approx 0.94$$

$\therefore$ the required pair is $(0, 0.94v_{rms})$.

IAPT answer: (B) | **Zigyan answer:** (B)

46. Formation of the iron peak elements $^{56}_{26}Fe$, $^{56}_{27}Co$ and $^{56}_{28}Ni$ by nuclear fusion marks the end of energy production in a star. If the mass of the iron core is greater than the Chandrasekhar mass (1.4 solar masses) the core cannot be supported by the degeneracy pressure of the electrons and will collapse to form a neutron star. Matter is crushed to nuclear densities with protons combining with electrons as $p^+ + e^- \rightarrow n + \nu_e$. Neutron stars whose masses are not too high are supported by neutron degeneracy pressure against gravitational collapse. The number of neutrinos released, when a neutron star of 1.4 solar masses forms, is approximately

Physical constants you may need....

Mass of proton $m_p = 1.67 \times 10^{-27}$ kg

Mass of neutron $m_n = 1.67 \times 10^{-27}$ kg

Mass of Sun $M = 2.0 \times 10^{30}$ kg

(A) 7.77×10^{56} (B) 1.74×10^{57} (C) 8.68×10^{56} (D) 8.38×10^{57}

Solution · Q46 **Answer: (A)**

One neutrino is released for each proton that turns into a neutron.

The iron core is taken as $^{56}_{26}Fe$, with 26 protons in 56 nucleons.

Number of nucleons in the core:

$$N = \frac{1.4 \times 2.0 \times 10^{30}}{1.67 \times 10^{-27}} \approx 1.677 \times 10^{57}$$

Number of neutrinos:

$$N_\nu = \frac{26}{56} \times 1.677 \times 10^{57}$$

$$\Rightarrow N_\nu \approx 7.78 \times 10^{56}$$

The nearest option is 7.77×10^{56}.

IAPT answer: (A) | **Zigyan answer:** (A)

47. The Seebeck coefficient of a material characterizes the voltage built up when a small temperature gradient is set up across it. It is defined by the relation $S = -\frac{V_{left} - V_{right}}{T_{left} - T_{right}}$. Only the relative Seebeck coefficients of materials may be determined since, connecting a voltmeter introduces other voltages. The relative Seebeck coefficients of some elemental materials in μV/K are: (A) Aluminium: 3.5 (B) Carbon: 3 (C) Sodium: −2 (D) Platinum: 0. The absolute Seebeck coefficient of Platinum is −5 μV at room temperature. The combination of two metals which will give maximum voltage difference when used to make a thermocouple is

(A) (A, D) (B) (C, D) (C) (A, C) (D) (B, C)

Solution · Q47 **Answer: (C)**

A common offset cancels in a difference, so the relative values can be used directly.

(A, D): 3.5 − 0 = 3.5 μV/K

(C, D): 0 − (−2) = 2 μV/K

(A, C): 3.5 − (−2) = 5.5 μV/K

(B, C): 3 − (−2) = 5 μV/K

The difference is largest for aluminium with sodium, (A, C).

IAPT answer: (C) | **Zigyan answer:** (C)

48. The mean power received per unit area just outside Earth's atmosphere from the Sun known as the solar constant, is 1.362 kilowatt per square meter (kW/m^2). For receiving this much power per unit area at Earth, the Sun, if it is radiating like a black body, must have a surface temperature of

Physical constants you may need....

Stefan's constant $\sigma = 5.67 \times 10^{-8}$ W / m^{2}K^4

Astronomical unit = 1.50×10^{11} m

Radius of Sun R = 6.96×10^{8} m

(A) 5349 K (B) 5779 K (C) 5709 K (D) 5479 K

Solution · Q48 **Answer: (B)**

Let R be the radius of the Sun, d the distance of the Earth from it and S the solar constant.

$$S = \sigma T^4 \left(\frac{R}{d}\right)^2$$

$$\Rightarrow T^4 = \frac{S}{\sigma}\left(\frac{d}{R}\right)^2$$

$$\Rightarrow T^4 = \frac{1362}{5.67 \times 10^{-8}} \times \left(\frac{1.50 \times 10^{11}}{6.96 \times 10^{8}}\right)^2$$

$$\Rightarrow T^4 \approx 1.116 \times 10^{15}\ K^4$$

$$\therefore T \approx 5779\ K$$

IAPT answer: (B) | **Zigyan answer:** (B)

PART A-2 · ONE OR MORE CORRECT OPTIONS

Q. 49 – 60 · 6 marks only if all correct options are marked · no negative marking

49. Consider the electromagnetic radiation emitted by two stars. The hotter star will

(A) emit more radiation at all wavelengths

(B) have a higher frequency of peak emission in its spectrum

(C) radiate energy at more than one wavelength

(D) exhibit a continuous spectrum

Solution · Q49 **As per Zigyan: (A), (B), (C), (D)**

The stars are treated as black bodies, compared for equal surface areas.

(A) The hotter body emits more at every wavelength. ∴ true.

(B) By Wien's law, the peak frequency rises with temperature:

$$\nu_{peak} \propto T$$

∴ true.

(C), (D) Thermal radiation is spread continuously over wavelengths. ∴ both true.

Reference: OpenStax Astronomy 2e, section 5.2 'The Electromagnetic Spectrum', Radiation Laws: a hotter blackbody gives out more power at all wavelengths than a cooler one, and its emission peaks at a shorter wavelength.

Reference: NCERT Physics Class XI (Part II), Chapter 10 'Thermal Properties of Matter', section 10.9.4: thermal radiation at any temperature is not limited to one or a few wavelengths; its spectrum is continuous.

IAPT answer: (A), (B), (C), (D) | **Zigyan answer:** (A), (B), (C), (D)

50. Because of the precession of the axis of rotation of Earth

(A) the polaris is not always our 'pole star'

(B) the average length of a sidereal day changes slowly with time

(C) the declinations of the stars change slowly with time

(D) the Vernal Equinox moves with respect to the stars

Solution · Q50 **Answer: (A), (C), (D)**

Precession swings Earth's axis slowly round a cone, at an almost steady rate.

(A) The celestial pole shifts among the stars, so the pole star changes. ∴ true.

(B) Steady precession does not make the mean sidereal day keep changing in length. ∴ false.

(C) The celestial equator tilts along with the axis, so declinations change. ∴ true.

(D) The equinox, where the celestial equator cuts the ecliptic, slides westward among the stars. ∴ true.

IAPT answer: (A), (C), (D) | **Zigyan answer:** (A), (C), (D)

51. A planet orbits the Sun at a distance of 4.0 AU from the Sun. The orbital speed (v_o) and the time period (T) of the planet are approximately

Physical constants you may need....

Universal gravitational constant $G = 6.67 \times 10^{-11}\ Nm^2 / kg^2$

Astronomical unit $= 1.50 \times 10^{11}$ m

Mass of Sun $M = 2.0 \times 10^{30}$ kg

(A) $v_o = 7.92$ km/s (B) $v_o = 14.93$ km/s (C) T = 4 years (D) T = 8 years

Solution · Q51 **Answer: (B), (D)**

By Kepler's third law, with r in AU and T in years:

$$T^2 = r^3$$

$$\Rightarrow T = 4^{3/2} = 8$$

∴ The time period is 8 years.

For the circular orbit,

$$r = 4 \times 1.50 \times 10^{11}\ m = 6.0 \times 10^{11}\ m$$

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 2.0 \times 10^{30}}{6.0 \times 10^{11}}}$$

$$\Rightarrow v \approx 1.49 \times 10^4\ m/s \approx 14.9\ km/s$$

∴ (B) and (D) are true.

IAPT answer: (B), (D) | **Zigyan answer:** (B), (D)

52. The rotation period of a spherical moon about its own axis is equal to its period of revolution round its parent planet. Which of the following statements is/are true?

(A) If the orbital and spin angular momentum vectors of the moon are parallel to each other then, the moon will always show the same portion of its surface to the planet

(B) If the spin angular momentum vector of the moon lies in its orbital plane, then every portion of the surface of the moon may be seen from the planet

(C) If the orbital and spin angular momentum vectors of the moon are antiparallel with respect to each other then, viewed from the planet, the moon will appear to be non-rotating

(D) If the spin angular momentum vector of the moon lies in its orbital plane, then, viewed from the planet, the moon will appear to be rotating with a higher angular speed

Solution · Q52 **As per Zigyan: (A), (B), (D)**

Take a circular orbit; ω is both the spin rate and the orbital rate.

As seen from the planet, the moon turns with angular velocity

$$\vec{\omega}_{\text{rel}} = \vec{\omega}_{\text{s}} - \vec{\omega}_{\text{o}}$$

(A) For parallel spin:

$$\left|\vec{\omega}_{\text{rel}}\right| = \omega - \omega = 0$$

The same face stays towards the planet. ∴ true.

(B) The axis stays fixed in the orbital plane. Each end points to the planet once per orbit, showing both halves. ∴ true.

(C) For antiparallel spin:

$$\left|\vec{\omega}_{\text{rel}}\right| = \omega + \omega = 2\omega$$

It appears to rotate. ∴ false.

(D) The two angular velocities are perpendicular:

$$\left|\vec{\omega}_{\text{rel}}\right| = \sqrt{\omega^2 + \omega^2} = \sqrt{2}\ \omega$$

This is more than ω. ∴ true.

Why Zigyan differs from IAPT: seen from the planet, this moon turns about 1.41 times as fast as it spins, so (D) holds too.

Check: tracking the moon's orientation numerically against the planet–moon line gives a steady turning rate of 1.41 times the spin rate when the axis lies in the orbital plane, no turning for parallel spin and twice the spin rate for antiparallel spin.

IAPT answer: (A), (B) | **Zigyan answer:** (A), (B), (D)

53. The true statement(s) for the function $f(x) = \begin{cases} \frac{\sin|x|}{|x|} & \text{if } x \neq 0 \\ 0 & \text{if } x = 0 \end{cases}$ is / are

(A) $\lim_{x \to 0} f(x)$ exists

(B) $\lim_{x \to 0} f(x)$ does not exist

(C) f is differentiable at x = 0

(D) f has removable discontinuity at x = 0

Solution · Q53 **Answer: (A), (D)**

For non-zero x, put

$$t = |x|$$

$$\lim_{x \to 0} f(x) = \lim_{t \to 0} \frac{\sin t}{t} = 1$$

The limit exists: (A) true, (B) false.

$$f(0) = 0 \neq 1$$

So f is not continuous at zero, hence not differentiable there. ∴ (C) false.

As the limit exists, the discontinuity is removable. ∴ (D) true.

IAPT answer: (A), (D) | **Zigyan answer:** (A), (D)

54. Consider the differential equation $x\frac{dy}{dx} + 3y = x^3$. Which of the following is/are true?

(A) $3x^3$ is an integrating factor of this equation

(B) $y = \frac{x^3}{6} + \frac{2023}{x^3}$ is a solution of this equation

(C) $y = \frac{x^3}{6} - \frac{8}{2023x^3}$ is a solution of this equation

(D) The equation is a homogeneous differential equation

Solution · Q54 **Answer: (A), (B), (C)**

In standard linear form:

$$\frac{dy}{dx} + \frac{3}{x}y = x^2$$

$$\text{I.F.} = e^{\int (3/x)dx} = x^3$$

A constant multiple of an integrating factor is also one. ∴ (A) true.

$$\Rightarrow yx^3 = \int x^5\, dx$$

$$\Rightarrow y = \frac{x^3}{6} + \frac{C}{x^3}$$

$$C = 2023 \text{ and } C = -8/2023$$

These values give (B) and (C). ∴ both true.

For (D),

$$\frac{dy}{dx} = x^2 - \frac{3y}{x}$$

The right side is not a function of y/x alone, so the equation is not homogeneous. ∴ false.

IAPT answer: (A), (B), (C) | **Zigyan answer:** (A), (B), (C)

55. Consider the LPP (Linear Programming Problem) Max $Z = x + y$ subject to the constraints $x + 3y \geq 6$, $y \leq 3$, $x + y \leq 4$, $x, y \geq 0$ Which of the following is/are true?

(A) $x = 1, y = 2$ is a feasible solution of the LPP

(B) $x = 2, y = 2$ is an optimal solution of the LPP

(C) The only optimal solutions of the LPP are $x = 1, y = 3$ and $x = 3, y = 1$

(D) $x = 3, y = 1$ is an optimal solution of the LPP

Solution · Q55 **Answer: (A), (B), (D)**

One constraint limits the objective:

$$Z = x + y \leq 4$$

(A) For the point (1, 2):

$$1 + 3(2) = 7 \geq 6,\ 2 \leq 3,\ 1 + 2 = 3 \leq 4$$

It is feasible. ∴ true.

(B), (D) The points (2, 2) and (3, 1) are feasible and reach the maximum, 4. ∴ both true.

(C) Every point on the segment joining (1, 3) and (3, 1) is optimal, so there are infinitely many. ∴ false.

IAPT answer: (A), (B), (D) | **Zigyan answer:** (A), (B), (D)

56. For vectors A, B & C in three dimensional Euclidean space, let AB = A × B stand for the cross product, [A, B] = AB − BA for the commutator of A & B and {A, B, C} = (AB) C − A (BC) for the associator of A, B & C. Then which of the following relations hold true?

(A) $A^2 = 0$ for $A \neq 0$

(B) $[A, B] = 0$ for $A \neq B$ and $A, B \neq 0$

(C) $\{A, B, C\} = 0$ for $A \neq B \neq C$ and $A, B, C \neq 0$

(D) $A(BC) + B(CA) + C(AB) = 0$ for $A \neq B \neq C$ and $A, B, C \neq 0$

Solution · Q56 **As per Zigyan: (A), (D)**

(A) For any vector A,

$$|A \times A| = |A||A| \sin 0° = 0$$

A^2 means $A \times A$. ∴ true.

(B) As BA is minus AB,

$$[A, B] = 2(A \times B)$$

Non-zero for non-parallel vectors. ∴ false.

(C) With unit vectors i, j, k, take A as i, B as j, C as i + j:

$$(AB)C = k \times (i + j) = j - i$$

$$A(BC) = i \times (-k) = j$$

$$\Rightarrow \{A, B, C\} = -i \neq 0$$

∴ false.

(D) Jacobi identity, using

$$A \times (B \times C) = B(A \cdot C) - C(A \cdot B)$$

The three cyclic expansions cancel. ∴ true.

Why Zigyan differs from IAPT: A squared is A crossed with itself, zero for every vector.

Reference: NCERT Physics Class XI (Part I), Chapter 6 'Systems of Particles and Rotational Motion', section 6.5 'Vector Product of Two Vectors': the vector product of any vector with itself is the null vector.

IAPT answer: (D) | **Zigyan answer:** (A), (D)

57. An artificial satellite is moving in an orbit around the Earth with orbital period of 8 hours, from west to east, with its orbit making an angle of 30° with equator. An observer on the equator will see it

(A) again after 6 hour, moving from east to west

(B) again after about 11 hours, moving from west to east

(C) going up to about 46.8° from the equatorial plane

(D) going up to about 43.2° from the equatorial plane

Solution · Q57 **As per Zigyan: (D)**

The satellite outruns Earth's spin, so it moves west to east. ∴ (A) false.

It reappears after time T (in hours):

$$\frac{1}{T} = \frac{1}{8} - \frac{1}{24}$$

$$\Rightarrow T = 12\ \text{h}$$

∴ (B) false.

For the orbit radius (t is 8 hours),

$$g = 9.8\ \text{m s}^{-2},\ R = 6400\ \text{km}$$

$$r^3 = \frac{gR^2t^2}{4\pi^2}$$

$$\Rightarrow r \approx 2.04 \times 10^4\ \text{km}$$

The angle is greatest when the satellite, farthest from the equator, crosses the observer's meridian:

$$\tan\theta = \frac{r\sin 30°}{r\cos 30° - R}$$

$$\Rightarrow \theta \approx 42°$$

The nearer listed value is 43.2°: (D) true, (C) false.

Why Zigyan differs from IAPT: in 12 h the satellite makes one and a half revolutions and the observer half a turn, repeating the view mirrored north–south.

Reference: NCERT Physics Class XI (Part I), Chapter 7 'Gravitation', section 7.9 'Earth Satellites': the square of a satellite's period is proportional to the cube of its orbit radius, so an 8 hour period fixes the size of the orbit.

Check: following the satellite and an equatorial observer numerically for three days, each rise came 12.0 hours after the one before, and the angle from the equatorial plane never exceeded 42.2°.

IAPT answer: (B), (D) | **Zigyan answer:** (D)

58. A particle of mass 'm' is moving under the influence of a central force; the correct statement(s) is/are

(A) The motion always remains constrained to be in a plane

(B) The trajectory will always be elliptical

(C) The total angular momentum remains constant

(D) The torque about the force center is always zero

Solution · Q58 **Answer: (A), (C), (D)**

A central force acts along the line to the centre, so about it

$$\tau = r \times F = 0$$

$\therefore$ (D) true.

$$\frac{dL}{dt} = \tau = 0$$

So angular momentum stays constant. $\therefore$ (C) true.

The position and velocity stay perpendicular to this fixed L, so the motion stays in one plane (if L vanishes, along a line). $\therefore$ (A) true.

The path depends on the force law and starting conditions; it may even be a hyperbola. $\therefore$ (B) false.

IAPT answer: (A), (C), (D) | **Zigyan answer:** (A), (C), (D)

59. When a raw poori round (kneaded wheat dough rolled into thin rounds) is slipped into hot oil and the hot oil is swished immediately over it repeatedly, the poori puffs up because

(A) the dough has comparatively low heat conductivity

(B) hot oil causes a crust to form

(C) the density of steam is low

(D) the matrix of proteins in the dough formed during kneading helps trap gases

Solution · Q59 **Answer: (A), (B), (C), (D)**

In hot oil, water in the dough turns into steam.

(A) The dough conducts heat slowly, so the faces cook while the moist inside is still giving off steam. $\therefore$ true.

(B) Hot oil swished on top quickly forms a crust there too, holding the steam in. $\therefore$ true.

(C) Steam has very low density, so a little water makes a large volume that pushes the layers apart. $\therefore$ true.

(D) The stretchy protein (gluten) network traps the gas. $\therefore$ true.

IAPT answer: (A), (B), (C), (D) | **Zigyan answer:** (A), (B), (C), (D)

60. Two positively charged conducting spheres A and B with +Q charge on each, are placed on the x-axis at (a, 0) and (– a, 0). A very small metallic ball with charge +q is gently placed at the origin (midway between the two spheres). The small ball with charge +q, in the middle, is

(A) in stable equilibrium if constrained to move only along x-axis

(B) in unstable equilibrium if constrained to move only perpendicular to the x-axis

(C) always in unstable equilibrium

(D) always in neutral equilibrium

Solution · Q60 **Answer: (A), (B)**

Take the sphere charges as point charges at their centres.

(A) For a small shift x along the axis, the force on the ball is

$$F = kQq\left[\frac{1}{(a+x)^2} - \frac{1}{(a-x)^2}\right]$$

$$\Rightarrow F \approx -\frac{4kQqx}{a^3}$$

It pulls the ball back: stable. ∴ true.

(B) For a small shift y at right angles,

$$F = \frac{2kQqy}{\left(a^2+y^2\right)^{3/2}}$$

It pushes the ball farther out: unstable. ∴ true.

(C), (D) Being stable along x, the ball is neither always unstable nor neutral. ∴ both false.

IAPT answer: (A), (B) | **Zigyan answer:** (A), (B)

ANSWER KEY

NSEA 2023 · PAPER CODE 41

60
QUESTIONS · 216 MARKS

IAPT final answer key for paper code 41. ★ marks an answer given as per Zigyan.

1	(D)	2	(C)	3	(D)	4	(A)	5	(A)
6	(C)	7	(D)	8	(B)	9	(B)	10	(A)
11	(B)	12	(A)	13	(A)	14	(C)	15	(A)
16	(B)	17	(C)	18	(B)	19	(A)	20	(C)
21	(D)	22	(C)★	23	(C)	24	(C)	25	(D)
26	(A)	27	(B)	28	(D)	29	(B)	30	(A)
31	(A)	32	(B)	33	(C)	34	(D)	35	(A)
36	(C)	37	(D)	38	(D)	39	(C)	40	(A)
41	(C)	42	(B)	43	(C)	44	(C)	45	(B)
46	(A)	47	(C)	48	(B)	49	(A), (B), (C), (D)★	50	(A), (C), (D)
51	(B), (D)	52	(A), (B), (D)★	53	(A), (D)	54	(A), (B), (C)	55	(A), (B), (D)
56	(A), (D)★	57	(D)★	58	(A), (C), (D)	59	(A), (B), (C), (D)	60	(A), (B)

★ Answers as per Zigyan

- **Q22** — As per Zigyan: (C); IAPT key (C).
- **Q49** — As per Zigyan: (A), (B), (C), (D); IAPT key (A), (B), (C), (D).
- **Q52** — As per Zigyan: (A), (B), (D); IAPT key (A), (B).
- **Q56** — As per Zigyan: (A), (D); IAPT key (D).
- **Q57** — As per Zigyan: (D); IAPT key (B), (D).

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OLYMPIADS · 2026

Olympiad results



TOP ACHIEVEMENT · CHEMISTRY

Qualified the Chemistry Olympiad twice, and selected for the HBCSE camp.

Saksham Bishnoi reached the national stage of the Chemistry Olympiad in two consecutive years and was selected for the Orientation-cum-Selection Camp at HBCSE, Mumbai. 4 Years Classroom - the same student who took AIR 168 in JEE Advanced 2026.

Qualified twice | HBCSE selection camp | Only student from Faridabad

Above MAS means above the **Minimum Admissible Score**: clearing it puts a student in the national band for their subject. It is a real threshold, not a participation marker.

CHEMISTRY · ABOVE MAS



Sulokya Bibhuty
Class XII
3 Years Classroom
Above MAS



Anay Gupta
Class XI
3 Years Classroom
Above MAS



Akshat Khator
Class XI
3 Years Classroom
Above MAS



Harshit Goyal
Class XII
4 Years Classroom
Above MAS



Hardik Sharma
Class XI
3 Years Classroom
Above MAS



Aarush Kumar
Class XII
1 Year Classroom
Above MAS

PHYSICS · ASTRONOMY · MATHEMATICS

PHYSICS



Sulokya Bibhuty
Class XII
3 Years Classroom
Above MAS

PHYSICS



Saksham Bishnoi
Class XII
4 Years Classroom
Above MAS

ASTRONOMY



Sulokya Bibhuty
Class XI
3 Years Classroom
Above MAS

MATHEMATICS · IOQM



Priyanshi
Class XI
4 Years Classroom
IOQM Qualifier

OLYMPIADS WE PREPARE STUDENTS FOR

NSEP	NSEC	NSEB	NSEA	IOQM	NSEJS
Physics	Chemistry	Biology	Astronomy	Mathematics	Class X and below

The olympiad pathway starts in Class 8.

NSEJS is open to Class 10 and below - the habit of staying with one hard problem is the one JEE Advanced rewards.

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RESULTS · 2021 – 2026

Our toppers, year by year

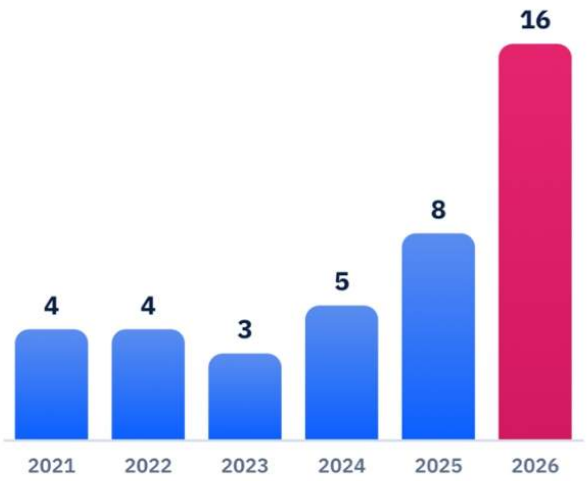
40
JEE Advanced selections in 6 years

AIR 168
best rank — Saksham Bishnoi, 2026

16 of 35
students selected, JEE Advanced 2026

14 of 35
above 98 percentile, JEE Main 2026

JEE ADVANCED SELECTIONS PER YEAR



BEST RANK EACH YEAR

YEAR	JEE ADVANCED	JEE MAIN
2026	**Saksham Bishnoi** AIR 168 · 4 Years Classroom	**Saksham Bishnoi** AIR 811 · 99.95 %ile
2025	**Chakshu** AIR 4,233 · 2 Years Classroom	**Chakshu** AIR 8,538 · 99.44 %ile
2024	**Harshit** AIR 777 · 2 Years Classroom	**Harshit** AIR 1,473 · 99.91 %ile
2023	**Aditya Jain** AIR 2,373 · 2 Years Classroom	**Aditya Jain** AIR 2,503 · 99.79 %ile
2022	**Rachit Sharma** AIR 698 · 1 Year Classroom	**Rachit Sharma** AIR 1,016 · 99.90 %ile
2021	**Sparsh Mittal** AIR 2,237 · 1 Year Classroom	**Sparsh Mittal** AIR 1,562

JEE ADVANCED 2026 — THIRTEEN NAMED SELECTIONS



Saksham Bishnoi
AIR 168
4 Years Classroom



Sulokya Bibhuty
AIR 1,315
3 Years Classroom



Aarush
AIR 2,699
1 Year Classroom



Manishka
AIR 2,869
4 Years Classroom



Oojit Kumar
AIR 5,765
4 Years Classroom



Harshit Goyal
AIR 6,407
4 Years Classroom



Pranab Sharma
AIR 6,750
3 Years Classroom



Aditya Dhar
AIR 15,183
3 Years Classroom



Arpit Anshuman
AIR 19,308
4 Years Classroom



Lokesh
AIR 22,857
3 Years Classroom



Arjun
AIR 24,674
3 Years Classroom



Sanyam Gulyani
AIR 25,123
1 Year Classroom



Saket
AIR 27,628
3 Years Classroom

Sixteen students of the 2026 batch were selected in JEE Advanced; the thirteen above are named with their All India Rank.

JEE MAIN 2026 — TOP SIX, WITH PERCENTILE



Saksham Bishnoi
AIR 811
99.95 %ile
4 Years Classroom



Sulokya Bibhuty
AIR 1,095
99.94 %ile
3 Years Classroom



Harshit Goyal
AIR 2,662
99.83 %ile
4 Years Classroom



Manishka
AIR 4,817
99.70 %ile
4 Years Classroom



Oojit Kumar
AIR 5,040
99.69 %ile
4 Years Classroom



Aarush
AIR 5,276
99.67 %ile
1 Year Classroom

14 of the 35 students in the 2026 batch scored above the 98th percentile in JEE Main.

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