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PREVIOUS YEAR PAPER · 2021-22

OLYMPIAD · STAGE I

IOQA

Indian Olympiad Qualifier in Astronomy (Part I)

2021-22

Question paper, answer key and Zigyan solutions

32	120	75 min	41
Questions	Maximum marks	Time	Paper code

Question paper and official answer key: Indian Association of Physics Teachers (IAPT), IOQA 2021-22, paper code 41.
Solutions and notes: Zigyan. This booklet is not an IAPT publication.

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Sulokya Bibhuty

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- 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
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Given in the question paper

Physical constants you may need….

Magnitude of charge on electron $e = 1.60 \times 10^{-19} C$	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 $\sigma = 5.67 \times 10^{-8} W / m^2 K^4$	

PART A-1 · ONE CORRECT OPTION

Q. 1 – 24 · +3 for a correct answer, –1 for a wrong one

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) $\frac{(m_1 + m_2)v}{m_1 g\sqrt{2}}$

Solution · Q1 **Answer: (A)**

The balls leave the ground together and meet in air.

So both always have the same vertical velocity.

Call it u_y just before the collision. By conservation of vertical momentum,

$$(m_1 + m_2)V_y = m_1 u_y + m_2 u_y$$

$$\Rightarrow V_y = u_y$$

Hence the time of flight does not change.

$$t = \frac{2v\sin 45^\circ}{g}$$

$$\Rightarrow t = \frac{v\sqrt{2}}{g}$$

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

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) $[5e]e^{-x}$

Solution · Q2 **Answer: (B)**

Integrating factor:

$$\text{I.F.} = e^{x}$$

$$\frac{d}{dx}(ye^{x}) = A$$

$$\Rightarrow ye^{x} = Ax + C$$

Using the given condition,

$$5e = A + C$$

$$\Rightarrow C = 5e - A$$

$$\therefore y = [5e + A(x - 1)]e^{-x}$$

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

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

Solution · Q3 **Answer: (B)**

Flux ratio of Sirius (S) to Castor (C):

$$\frac{F_S}{F_C} = 10^{0.4(1.6 + 1.4)}$$

$$\Rightarrow \frac{F_S}{F_C} = 10^{1.2}$$

$$\Rightarrow \frac{F_S}{F_C} = \left(10^{0.3}\right)^4$$

$$\Rightarrow \frac{F_S}{F_C} = 2^4 = 16$$

Both collect equal power (D in inch):

$$F_S \times 1^2 = F_C \times D^2$$

$$\Rightarrow D = \sqrt{16} = 4 \text{ inch}$$

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

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) $\frac{6\pi}{\sqrt{3}}$

Solution · Q4 **Answer: (B)**

Circumradius of the triangle:

$$R = \frac{L}{\sqrt{3}}$$

Required ratio:

$$\frac{\pi R^2}{\frac{\sqrt{3}}{4}L^2}$$

$$= \frac{\pi L^2 / 3}{\sqrt{3}\ L^2 / 4}$$

$$= \frac{4\pi}{3\sqrt{3}}$$

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

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

Solution · Q5 **Answer: (A)**

Frequency is fixed by the source, so f does not change.

The speed v of light is smaller in water than in air.

$$\lambda = \frac{v}{f}$$

$\therefore$ λ decreases.

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

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) $d > \frac{1.22\lambda u r_o}{f}$

Solution · Q6 **Answer: (C)**

By Rayleigh's criterion, the angle between the two points must exceed the limit of resolution:

$$\frac{r_o}{u} > \frac{1.22\lambda}{d}$$

$$\Rightarrow u < \frac{r_o d}{1.22\lambda}$$

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

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 $r_0 \le r \le R$,

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

Solution · Q7 **Answer: (A)**

In the outer region, with k a constant,

$$\rho(r) = \frac{k}{r}$$

With a core of mass M_0,

$$M(r) = M_0 + \int_{r_0}^{r} 4\pi x^2 \left(\frac{k}{x}\right) dx$$

$$\Rightarrow M(r) = M_0 + 2\pi k(r^2 - r_0^2)$$

$$g(r) = \frac{GM(r)}{r^2}$$

$$\Rightarrow g(r) = 2\pi Gk + \frac{G\left(M_0 - 2\pi k r_0^2\right)}{r^2}$$

This has the form

$$A + \frac{B}{r^2}$$

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

8. Given f(x) is a continuous function such that for $x \le 1$, $f(x) = 5e^{-(x-1)^2}$ and for $x \ge 1$, $f(x) = \frac{K}{(x+4)^2}$.

The value of K is

(A) $\frac{1}{5}$ (B) 5

(C) 25 (D) 125

Solution · Q8 **Answer: (D)**

For continuity, both expressions give the same value at the joining point.

$$5e^0 = \frac{K}{(1+4)^2}$$

$$\Rightarrow K = 125$$

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

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

Solution · Q9 **Answer: (C)**

M is the same in both estimates, so AD^2 does not change.

The old and new diameters are 14 km and 20 km.

$$0.15 \times 14^2 = A \times 20^2$$

$$\Rightarrow A = 0.0735 \approx 0.07$$

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

10. The area in the region $1 \le x \le 2$ 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

Solution · Q10 **Answer: (A)**

In the given interval the line lies above the curve.

Required area:

$$S = \int_1^2 (2x + 10 - 3x^2)\,dx$$

$$\Rightarrow S = [x^2 + 10x - x^3]_1^2$$

$$\Rightarrow S = 16 - 10 = 6\ cm^2$$

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

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

Solution · Q11 **Answer: (A)**

The Summer Triangle joins three bright stars of three different constellations:

Vega (Lyra), Altair (Aquila) and Deneb (Cygnus).

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

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

Solution · Q12 **Answer: (C)**

Direction ratios of AB are 1, 3, −4 and those of AC are 3, 9, r − 5.

For collinear points,

$$\frac{3}{1} = \frac{9}{3} = \frac{r-5}{-4}$$

$$\Rightarrow r - 5 = -12$$

$$\therefore r = -7$$

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

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

Solution · Q13 **Answer: (C)**

Distance in parsec is the reciprocal of the parallax in arcsecond.

Take the 200 stars as those with parallax 0.10″ or more. They lie within

$$d_1 = 10 \text{ pc}$$

Stars with parallax 0.025″ or more lie within

$$d_2 = 40 \text{ pc}$$

For a uniform distribution, the number is proportional to the volume.

$$\frac{N_2}{N_1} = \left(\frac{40}{10}\right)^3$$

$$\Rightarrow \frac{N_2}{N_1} = 64$$

$$\Rightarrow N_2 = 64 \times 200$$

$$\therefore N_2 = 12800$$

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

14. The value of (x, y) for which z = 3x + 4y + 10 is a maximum under the constraints

$x + y \le 40$, $2x + 3y \le 90$, $x, y \ge 0$ is

(A) (0, 30) (B) (0, 40) (C) (40, 0) (D) (30, 10)

Solution · Q14 **Answer: (D)**

The two boundary lines:

$$x + y = 40 \text{ and } 2x + 3y = 90$$

$$\Rightarrow x = 30 \text{ and } y = 10$$

Corner points of the feasible region are (0, 0), (40, 0), (30, 10) and (0, 30).

$$z(0, 0) = 10$$

$$z(40, 0) = 130$$

$$z(30, 10) = 140$$

$$z(0, 30) = 130$$

∴ z is maximum at (30, 10).

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

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

Solution · Q15 **Answer: (C)**

The force acts along the line joining the planet and the Sun, so its torque about the Sun is zero.

Hence the angular momentum L of the planet (mass m) is constant, and the areal velocity is

$$\frac{dA}{dt} = \frac{L}{2m}$$

∴ The second law stays unchanged.

With the extra A/r^2 term, the force is no longer purely inverse square, so the first and third laws cannot be assured.

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

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

Solution · Q16 **Answer: (D)**

Globular clusters are old, tightly bound star clusters spread in a nearly spherical distribution around the galactic centre.

∴ They are primarily found in the halo of our galaxy.

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

17. Consider 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

Solution · Q17 **Answer: (A)**

Expanding each factor, the product is

$(1 + x + x^2 + ...)(1 + x^2 + x^4 + ...)(1 + x^3 + x^6 + ...)...$

So the coefficient of x^5 is the number of partitions of 5:

5, 4 + 1, 3 + 2, 3 + 1 + 1, 2 + 2 + 1, 2 + 1 + 1 + 1, 1 + 1 + 1 + 1 + 1

∴ The coefficient is 7.

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

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

Solution · Q18 **Answer: (D)**

Let a, b, c, d be a, ar, ar^2, ar^3.

From the sums of the roots,

$$a(1 + r) = 6$$

$$ar^2(1 + r) = 24$$

Dividing,

$$r^2 = 4$$

The negative value of r makes the product pq equal to 82944, which is not an option. So

$$r = 2 \text{ and } a = 2$$

The four numbers are 2, 4, 8, 16.

$$p = 2 \times 4 = 8$$

$$q = 8 \times 16 = 128$$

$$\therefore pq = 1024$$

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

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 %

Solution · Q19 **Answer: (B)**

For the potential energy,

$$\frac{\Delta V}{V} = \frac{\Delta K}{K} + 2\frac{\Delta x}{x}$$

Percentage error in V:

$0.5 + 2 \times 1$

$\therefore$ 2.5 %

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

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

Solution · Q20 **Answer: (D)**

The satellites are half an orbit apart. So while the lower one makes 8 orbits, the other makes 7.5 orbits.

With T_1 for the lower orbit and T_2 for the original orbit,

$$8T_1 = 7.5T_2$$

By Kepler's third law,

$$\frac{r}{40000} = \left(\frac{T_1}{T_2}\right)^{2/3}$$

$$\Rightarrow \frac{r}{40000} = \left(\frac{7.5}{8}\right)^{2/3}$$

$$\Rightarrow \frac{r}{40000} = \frac{3.84}{4}$$

$$\Rightarrow r = 38400 \text{ km}$$

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

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

Solution · Q21 **Answer: (B)**

Acceleration due to gravity on a planet:

$$g = \frac{GM}{R^2}$$

$$\frac{g_E}{g_M} = \frac{M_E}{M_M} \times \left(\frac{R_M}{R_E}\right)^2$$

$$\Rightarrow \frac{g_E}{g_M} = 10 \times \frac{1}{4}$$

$$\Rightarrow \frac{g_E}{g_M} = \frac{5}{2}$$

Maximum height for the same speed u and angle θ:

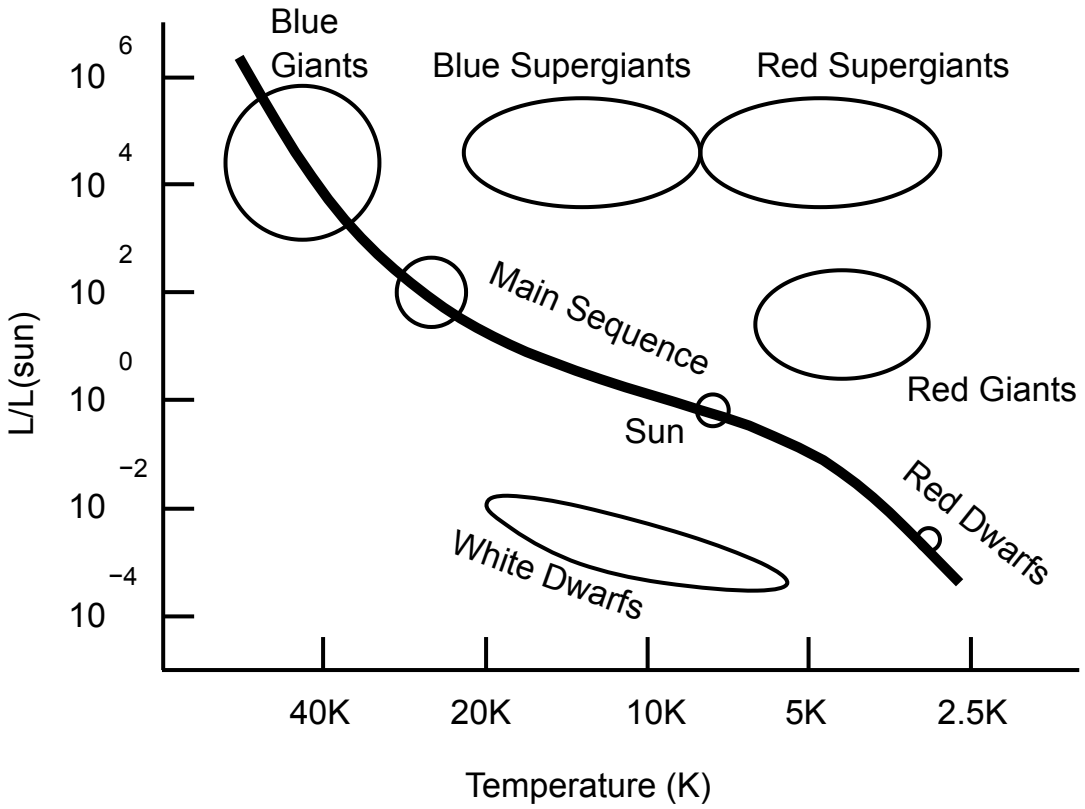
$$H = \frac{u^2 \sin^2\theta}{2g}$$

$$\frac{H_E}{H_M} = \frac{g_M}{g_E}$$

$$\therefore \frac{H_E}{H_M} = \frac{2}{5}$$

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

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

Solution · Q22 **Answer: (D)**

Taking ratios with the Sun,

$$\frac{R}{R_{sun}} = \sqrt{\frac{L}{L_{sun}}}\left(\frac{T_{sun}}{T}\right)^2$$

$$\Rightarrow 20 = \sqrt{\frac{L}{L_{sun}}} \times \left(\frac{6000}{3000}\right)^2$$

$$\Rightarrow \sqrt{\frac{L}{L_{sun}}} = 5$$

$$\Rightarrow \frac{L}{L_{sun}} = 25$$

On the diagram, a cool star at 3000 K with 25 times the Sun's luminosity falls in the Red Giant region.

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

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

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

Solution · Q23 **Answer: (B)**

In visible light, interstellar dust hides the centre of the Galaxy, so Statement I is true.

A supermassive black hole (Sagittarius A*) lies at the centre, so Statement II is true.

The centre is hidden by the dust, not by the black hole. Hence II does not explain I.

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

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.

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

Solution · Q24 **As per Zigyan: (C)**

Terrestrial planets have very little hydrogen gas, so Statement I is true.

For hydrogen molecules at about 300 K,

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

$$\Rightarrow v_{rms} = \sqrt{\frac{3 \times 8.31 \times 300}{2 \times 10^{-3}}}$$

$$\Rightarrow v_{rms} \approx 1.9 \text{ km s}^{-1}$$

Escape speed from the Earth:

$$v_{esc} \approx 11.2 \text{ km s}^{-1}$$

The other terrestrial planets also have escape speeds above this rms speed.

A typical hydrogen molecule is therefore slower than the escape speed, and Statement II is false.

Hydrogen is lost because the few fastest molecules, in the tail of the speed distribution, escape, and this leak adds up over a very long time.

Reference: NCERT Physics Class XI (Part II), Chapter 12 'Kinetic Theory', section 12.4.2: nitrogen molecules at 300 K have an rms speed of about 516 m s^{-1}, and at the same temperature lighter molecules have a greater rms speed.

Reference: NCERT Physics Class XI (Part I), Chapter 7 'Gravitation', section 7.8: the escape speed from the Earth is about 11.2 km s^{-1}.

Reference: OpenStax University Physics Volume 2, section 2.4 'Distribution of Molecular Speeds': a few molecules in the tail may move at several times the rms speed; those above escape velocity can leave, and over billions of years light hydrogen has been lost far more than nitrogen or oxygen.

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

PART A-2 · ONE OR MORE CORRECT OPTIONS

Q. 25 – 32 · 6 marks only if all correct options are marked · no negative marking

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

Physical constants you may need....

Speed of light in free space c = 3.0×10^8 m/s

(A) 5.55×10^4 km / sec
(B) 9.45×10^4 km / sec
(C) 0.315c
(D) 0.185c

Solution · Q25 **Answer: (A), (D)**

Photon energies for the two transitions of hydrogen:

$$E_{21} = 13.6\left(1 - \frac{1}{4}\right) \text{eV}$$

$$E_{31} = 13.6\left(1 - \frac{1}{9}\right) \text{eV}$$

The moving atom must approach the atom at rest. By the Doppler effect,

$$E_{31} = E_{21}\left(1 + \frac{v}{c}\right)$$

$$\Rightarrow 1 + \frac{v}{c} = \frac{32}{27}$$

$$\Rightarrow v = \frac{5}{27}c$$

$$\therefore v \approx 0.185c$$

$$\Rightarrow v \approx 5.55 \times 10^4 \text{ km / sec}$$

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

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

Solution · Q26 **As per Zigyan: (B)**

Free electrons move with the rod, so the magnetic field exerts the Lorentz force on each.

$$\vec{F} = -e\left(\vec{v} \times \vec{B}\right)$$

It separates charge along a suitably oriented rod, giving the emf. ∴ (B) true.

(A) An isolated rod develops this emf without any current. ∴ false.

(C) No changing magnetic field is needed. ∴ false.

(D) Dipole moments feel no net force in a uniform field, yet the emf appears. ∴ false.

Why Zigyan differs from IAPT: a rod moving through a uniform, steady field develops an emf although the field never changes; the force on its moving electrons explains it.

Reference: NCERT Physics Class XII (Part I), Chapter 6 'Electromagnetic Induction', section 6.6: for a rod moving in a uniform, time-independent field the emf follows from the Lorentz force on its charge carriers; an electric field made by a time-varying magnetic field is what explains the emf in a stationary conductor.

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

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) $\frac{25\pi}{12}$

Solution · Q27 **Answer: (A), (B), (C), (D)**

$$\cos 2\theta = \sin\frac{\pi}{3} = \frac{\sqrt{3}}{2}$$

$$\Rightarrow 2\theta = 2n\pi \pm \frac{\pi}{6}$$

$$\Rightarrow \theta = n\pi \pm \frac{\pi}{12}$$

Here n is any integer. The four listed angles are:

$$\text{(A)}\ \frac{\pi}{12} = 0 + \frac{\pi}{12}$$

$$\text{(B)}\ \frac{13\pi}{12} = \pi + \frac{\pi}{12}$$

$$\text{(C)}\ -\frac{11\pi}{12} = -\pi + \frac{\pi}{12}$$

$$\text{(D)}\ \frac{25\pi}{12} = 2\pi + \frac{\pi}{12}$$

∴ All four values are possible.

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

28. Let the 2 x 2 matrix $A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$, where a, b, c, d ϵ 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

Solution · Q28 **Answer: (B), (C)**

Taking determinants:

$$(\det A)^2 = \det(A^2) = 0$$

$$\Rightarrow \det A = 0$$

So the inverse does not exist and (C) is true.

By the Cayley-Hamilton theorem,

$$A^2 - (a + d)A + (\det A)I = O$$

$$\Rightarrow (a + d)A = O$$

The trace of the zero matrix is also zero.

$$\Rightarrow a + d = 0$$

∴ (B) is true.

(A) is false, since this non-zero matrix also has a zero square:

$$A = \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix}$$

(D) With zero trace, the zero square still requires

$$a^2 + bc = 0$$

Hence b and c are not arbitrary; (D) is false.

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

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

Solution · Q29 **Answer: (B), (C), (D)**

(A) The frequency of the transmitted light is unchanged, so each of its photons keeps its energy. ∴ false.

(B) Absorbed photons are removed from the beam. ∴ true.

(C) Scattered photons leave the direction of the beam. ∴ true.

(D) Partial reflection at the entry face sends some photons back. ∴ true.

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

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 $\tan^{-1}\sqrt{2}$.

Solution · Q30 **Answer: (A), (B), (D)**

Every edge has length L. Distance of a base corner from the centre of the base:

$$r = \frac{L}{\sqrt{2}}$$

Height:

$$h = \sqrt{L^2 - r^2} = \frac{L}{\sqrt{2}}$$

Surface area:

$$S = L^2 + 4 \times \frac{\sqrt{3}}{4}L^2 = \left(\sqrt{3}+1\right)L^2$$

Volume:

$$V = \frac{1}{3}L^2 h = \frac{L^3}{3\sqrt{2}}$$

Angle between the base and a triangular face:

$$\tan\varphi = \frac{h}{L/2} = \sqrt{2}$$

∴ (A), (B) and (D) are true; (C) is false.

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

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 $c = 3 \times 10^5$ 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.

Solution · Q31 **Answer: (A), (C)**

Redshift:

$$z = \frac{6606 - 6560}{6560} = \frac{46}{6560}$$

Speed of the galaxy:

$$v = cz \approx 2.1 \times 10^3 \text{ km/s}$$

∴ (A) is true.

The wavelength has increased, so the galaxy is red-shifted. (B) is false.

By Hubble's law,

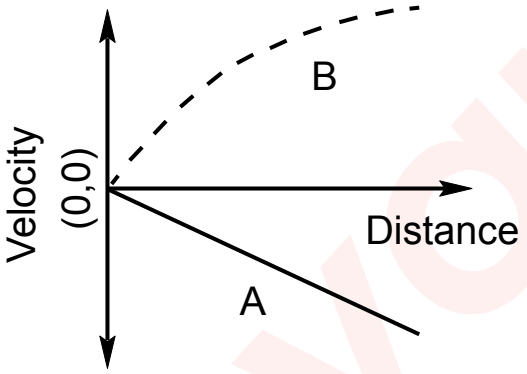
$$d = \frac{v}{H_0} \approx \frac{2100}{70} = 30 \text{ Mpc}$$

∴ (C) is true.

(D) A strong Hα emission line comes from gas ionised by hot young stars, so stars are forming. ∴ false.

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

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.

Solution · Q32 **Answer: (B), (C), (D)**

In A the velocity is negative, so its galaxies approach us and are blue-shifted. In B it is positive, so they recede and are red-shifted.

∴ (B) is true. B is not contracting, so (A) is false.

In A the speed of approach grows with distance. ∴ (C) is true.

In B the speed keeps rising with distance, and |z| rises with speed. ∴ (D) is true.

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

ANSWER KEY

IOQA 2021-22 · PAPER CODE 41

32
QUESTIONS · 120 MARKS

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

1	(A)	2	(B)	3	(B)	4	(B)	5	(A)
6	(C)	7	(A)	8	(D)	9	(C)	10	(A)
11	(A)	12	(C)	13	(C)	14	(D)	15	(C)
16	(D)	17	(A)	18	(D)	19	(B)	20	(D)
21	(B)	22	(D)	23	(B)	24	(C)★	25	(A), (D)
26	(B)★	27	(A), (B), (C), (D)	28	(B), (C)	29	(B), (C), (D)	30	(A), (B), (D)
31	(A), (C)	32	(B), (C), (D)						

★ Answers as per Zigyan

- **Q24** — As per Zigyan: (C); IAPT key (C).
- **Q26** — As per Zigyan: (B); IAPT key (B), (C).

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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

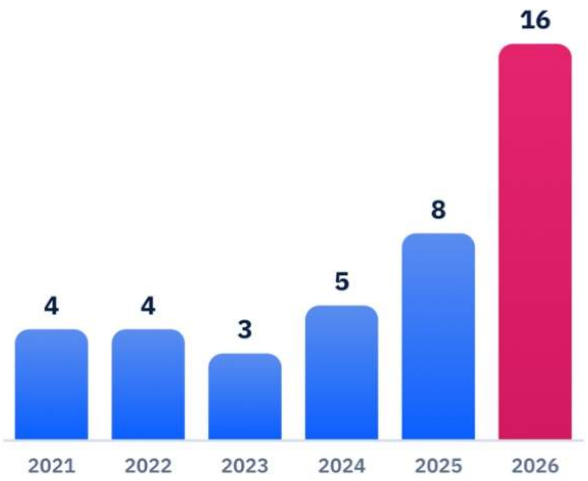
40
JEE Advanced selections in 6 years

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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