IOQP - 61

Time: 9:00 AM to 10:00 AM
Question Paper Code: 61

Student's Roll No:														

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

Instructions to Candidates:

1. Use of mobile phone, smart watch, and iPad during examination is STRICTLY PROHIBITED.
2. In addition to this question paper, you are given OMR Answer Sheet along with candidate's copy.
3. On the OMR sheet, make all the entries carefully in the space provided **ONLY** in **BLOCK CAPITALS** as well as by properly darkening the appropriate bubbles.

   Incomplete/ incorrect/ carelessly filled information may disqualify your candidature.
4. On the OMR Answer Sheet, use only **BLUE** or **BLACK BALL POINT PEN** for making entries and filling the bubbles.
5. Your **fourteen-digit roll number and date of birth** entered on the OMR Answer Sheet shall remain your login credentials means login id and password respectively for accessing your performance / result in Indian Olympiad Qualifier in Physics 2020-21 (Part I).
6. Question paper has two parts. In part A1 (Q. No.1 to 24) each question has four alternatives, out of which only one is correct. Choose the correct alternative and fill the appropriate bubble, as shown.

   Q.No. 12 (a) (●) (c) (d)

   In part A2 (Q. No. 25 to 32) each question has four alternatives out of which any number of alternative(s) (1, 2, 3, or 4) may be correct. You have to choose **all** correct alternative(s) and fill the appropriate bubble(s), as shown

   Q.No. 30 (a) (●) (c) (●)
7. For **Part A1**, each correct answer carries 3 marks whereas 1 mark will be deducted for each wrong answer. In **Part A2**, you get 6 marks if all the correct alternatives are marked and no incorrect. No negative marks in this part.
8. Rough work should be done only in the space provided. There are **08** printed pages in this paper.
9. Use of **non- programmable scientific** calculator is allowed.
10. No candidate should leave the examination hall before the completion of the examination.
11. After submitting answer paper, take away the question paper and candidate's copy of OMR for your reference

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

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

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

Instructions to Candidates (Continued) :

You may read the following instructions after submitting the answer sheet.

12. Comments/Inquiries/Grievances regarding this question paper, if any, can be shared on the Inquiry/Grievance column on www.iaptexam.in on the specified format till February 12, 2021.

13. The answers/solutions to this question paper will be available on the website: www.iapt.org.in by February 13, 2021.

14. CERTIFICATES and AWARDS:

Following certificates are awarded by IAPT to students, successful in the Indian Olympiad Qualifier in Physics 2020-21 (Part I)

(i) "CENTRE TOP 10 %"

(ii) "STATE TOP 1 %"

(iii) "NATIONAL TOP 1 %"

(iv) "GOLD MEDAL & MERIT CERTIFICATE" to all students who attend OCSC-2021 at HBCSE Mumbai

15. All these certificates (except gold medal) will be downloadable from IAPT website : www.iapt.org.in after March 15, 2020-21.

16. List of students (with centre number and roll number only) having score above MAS will be displayed on the website: www.iapt.org.in by **February 25, 2021. See the Minimum Admissible score Clause** on the Student's brochure on the web.

17. List of Students eligible for evaluation of IOQP 2020-21 (Part II) shall be displayed on www.iapt.org.in by March 1, 2021.

Physical constants you may need….

Mass of electron $m_e = 9.10\times10^{-31}$ kg	Magnitude of charge on electron $e = 1.60\times10^{-19}$ C
Mass of proton $m_p = 1.67\times10^{-27}$ kg	Permittivity of free space $\varepsilon_0 = 8.85\times10^{-12}$ $C^2N^{-1}m^{-2}$
Acceleration due to gravity $g = 9.8$ ms^{-2}	Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}
Universal gravitational constant $G = 6.67\times10^{-11}$ Nm^2Kg^{-2}	Planck's constant $h = 6.625 \times 10^{-34}$ Js
Universal gas constant $R = 8.31$ $Jmol^{-1}K^{-1}$	Faraday constant = 96,500 $Cmol^{-1}$
Boltzmann constant $k = 1.38\times10^{-23}$ JK^{-1}	Rydberg constant $R = 1.097 \times 10^7$ m^{-1}
Stefan's constant $\sigma = 5.67\times10^{-8}$ $Wm^{-2}K^{-4}$	Speed of light in free space $c = 3 \times 10^8$ ms^{-1}
Avogadro's constant $N_A = 6.023 \times 10^{23}$ mol^{-1}	

Question Paper Code: 61

Time: 60 Minute **Max. Marks: 120**

Attempt All Thirty Two Questions

A - 1

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

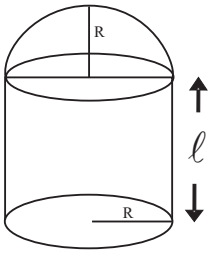
1. If speed of light c, Planck's constant h and gravitational constant G are chosen as fundamental quantities, dimensions of time in this system of units is

   (a) $ch^{3/2}G^{-3/2}$ (b) $c^{-2}G^{1/2}h$ (c) $c^{2}G^{1/2}h^{5/2}$ (d) $c^{-5/2}G^{1/2}h^{1/2}$

2. A solid hemisphere is cemented on the flat surface of a solid cylinder of same radius R and same material. The composite body is rotating about the axis of the cylinder of length ℓ with angular speed ω. The radius of gyration K is

   (a) $R\sqrt{\frac{2}{5}\left(\frac{15R+8\ell}{3R+2\ell}\right)}$ (b) $R\sqrt{\frac{1}{10}\left(\frac{15\ell+8R}{3\ell+2R}\right)}$

   (c) $R\sqrt{\frac{3}{10}\left(\frac{15R+8\ell}{3R+2\ell}\right)}$ (d) $R\sqrt{\frac{1}{10}\left(\frac{3\ell+2R}{15\ell+8R}\right)}$



3. The shortest period of rotation of a planet (considered to be a sphere of uniform density ρ) about its own axis, such that any mass m kept on its equator is just to fly off the surface, is

   (a) $T=\sqrt{\frac{5\pi}{\rho G}}$ (b) $T=\sqrt{\frac{\pi}{3\rho G}}$ (c) $T=\sqrt{\frac{3\pi}{\rho G}}$ (d) $T=\sqrt{\frac{5\pi}{3\rho G}}$

4. A body of mass 10 kg at rest explodes into two fragments of masses 3 kg and 7 kg. If the total kinetic energy of two pieces after explosion is 1680 J, the magnitude of their relative velocity in m/s after explosion is:

   (a) 40 (b) 50 (c) 70 (d) 80

5. A shot is fired at an angle α to the horizontal up a hill (Considered to be a long straight incline plane) of inclination β to the horizontal. It will strike the hill horizontally if

   (a) $\tan\alpha = 2\tan\beta$ (b) $\sin\alpha = \sin 2\beta$ (c) $\sin\alpha = 2\sin\beta$ (d) $\tan\alpha = 4\tan\beta$

6. A particle is executing Simple Harmonic Motion of time period $T = 4\pi^2$ in a straight line. Starting from rest, it travels a distance 'a' in the first second and distance 'b' in the next second travelling in the same direction. The amplitude of SHM is

(a) $\frac{2a^2}{3a-b}$ (b) $\frac{3a^2}{3a-2b}$ (c) $\frac{2a^2}{2a-b}$ (d) none of these

7. The kinetic energy of a particle moving along a circle of radius R depends upon the distance covered 's' as $KE = as^2$ where a is a constant. The magnitude of the force acting on the particle as a function of 's' is

(a) $\frac{2as^2}{R}$ (b) $\frac{2as^2}{m}$ (c) 2as (d) $2as\sqrt{1+\left(\frac{s}{R}\right)^2}$

8. The flow of water in a horizontal pipe is stream line flow. Along the pipe, at a point, where cross - sectional area is 10 cm^2, the velocity of water flow is 1.00 ms^{-1} and the pressure is 2000 Pa. The pressure of water at another point where cross - sectional area is 5 cm^2 is

(a) 2000 Pa (b) 1500 Pa (c) 3500 Pa (d) 500 Pa

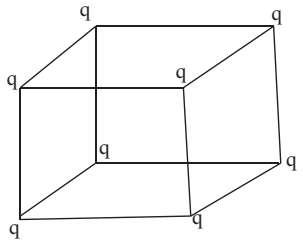
9. Three containers A, B and C are filled with water at different temperature. When 1 litre of water from A is mixed with 2 litre of water from B, the resulting temperature of mixture is 52^0 C. When 1 litre of water from B is mixed with 2 litre of water from C, the resulting temperature of mixture is 40^0 C. Similarly when 1 litre of water from C is mixed with 2 litre of water from A, the resulting temperature of mixture is 34^0 C. Temperature of mixture when one litre of water from each container is mixed (neglect the water equivalent of container) is

(a) 40^0 C (b) 42^0 C (c) 38^0 C (d) 45^0 C

10. Point charge q is kept at each corner of a cube of edge length ℓ. The resultant force of repulsion on any one of the charges due to all others is expressed as

(a) $\frac{\left(1+\frac{1}{2\sqrt{2}}+\frac{1}{3\sqrt{3}}\right)q^2}{\pi\varepsilon_0\ell^2}$ (b) $\frac{\left(\frac{1}{2\sqrt{2}}-1+\frac{1}{3\sqrt{3}}\right)q^2}{\pi\varepsilon_0\ell^2}$

(c) $\frac{(1-0.1775\ )q^2}{\pi\varepsilon_0\ell^2}$ (d) none of these



11. In an experiment with potentiometer, the balancing length is 250 cm for a cell. When the cell is shunted by a resistance of 7.5 Ω, balancing point is shifted by 25 cm. If the cell is shunted by a resistance of 20 Ω, the balancing length will be nearly

(a) 240 cm (b) 236 cm (c) 232 cm (d) 230 cm

12. One mole of a gas with $\gamma = \frac{5}{3}$ is mixed with two moles of another non-interacting gas with $\gamma = \frac{7}{5}$ The ratio of specific heats $\gamma = \frac{C_P}{C_V}$ of mixture is approximately

(a) 1.50 (b) 1.46 (c) 1.49 (d) 1.53

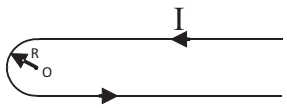
13. An ideal gas is expanding such that PT^3 = constant. The coefficient of volume expansion of the gas is

(a) $\frac{1}{T}$ (b) $\frac{2}{T}$ (c) $\frac{3}{T}$ (d) $\frac{4}{T}$

14. What is the magnetic induction B at the centre O of the semicircular arc if a current carrying wire has shape of an hair pin as shown in figure? The radius of the curved part of the wire is R, the linear parts are assumed to be very long.

(a) $B = \frac{\mu_0 I}{4\pi R}(2+\pi)$ (b) $B = \frac{\mu_0 I}{4R}(2+\pi)$

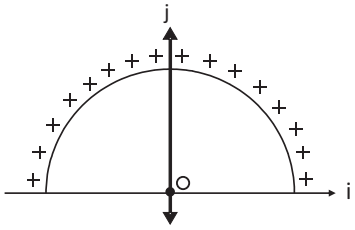
(c) $B = \frac{3\mu_0 I}{4R}(2+\pi)$ (d) $B = \frac{\mu_0}{4\pi}\frac{2I}{R}$



15. A thin semi-circular metal ring of radius R has a positive charge q distributed uniformly over its curved length. The resultant electric field $\vec{E}$ at the center O is

(a) $-\hat{j}\frac{q}{2\pi^2\varepsilon_0 R^2}$ (b) $+\hat{j}\frac{q}{2\pi^2\varepsilon_0 R^2}$

(c) $+\hat{j}\frac{q}{4\pi^2\varepsilon_0 R^2}$ (d) $-\hat{j}\frac{q}{4\pi^2\varepsilon_0 R^2}$



16. An Alternating Current is expressed as $i = i_1 \cos\omega t + i_2 \sin\omega t$. The RMS value of current is

(a) $\sqrt{\frac{(i_1+i_2)^2}{2}}$ (b) $\sqrt{\frac{i_1 i_2}{2}}$ (c) $\sqrt{\frac{(i_1^2+i_2^2)}{2}}$ (d) $\sqrt{\frac{(i_1-i_2)^2}{2}}$

17. A charge + q is placed at each of the points $x = x_0, x = 3x_0, x = 5x_0, x = 7x_0 \ldots\ldots\ldots\infty$ on the x-axis and a charge -q is placed at each of the points $x = 2x_0, x = 4x_0, x = 6x_0, x = 8x_0 \ldots\ldots\infty$ here x_0 is a positive constant. Take the electric potential at a point due to a charge q at a distance r from it to be $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$. The electric potential at the origin due to the above system of charges is

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}\frac{q}{x_0}\ln 2$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{x_0 2\ln 2}$ (d) infinite

18. The Nucleus $^{23}_{10}Ne$ decays by $\beta -$ emission through the reaction $^{23}_{10}Ne \rightarrow {}^{23}_{11}Na + {}^{0}_{-1}\beta + \bar{\upsilon} + \text{energy}$ The atomic masses are $^{23}_{10}Ne = 22.994466\,u$ and $^{23}_{11}Na = 22.989770\,u$, $^{0}_{-1}\beta = 0.000549$ u. The maximum kinetic energy that the emitted electron can ever have is

(a) 4.374 MeV (b) 3.862 MeV (c) 2.187 MeV (d) 1.931 MeV

19. The distance between two slits in Young's double slits experiment is d = 2.5 mm and the distance of the screen from the plane of slits is D = 120 cm. The slits are illuminated with coherent beam of light of wavelength λ = 600 nm. The minimum distance (from the central maximum) of a point where the intensity reduces to 25% of maximum intensity is

(a) 24 μm (b) 48 μm (c) 96 μm (d) 120 μm

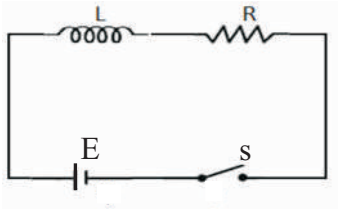
20. What amount of heat will be generated in a coil of resistance R (ohm) due to a total charge Q (coulomb) passing through it if the current in the coil decreases down to zero halving its value every Δt second?

(a) $\frac{1}{2}\frac{Q^2R}{\Delta t}$ (b) $\frac{Q^2R}{\Delta t}\ln 2$ (c) $\frac{1}{2}\frac{Q^2R}{\Delta t}\ln 2$ (d) $\frac{1}{4}\frac{Q^2R}{\Delta t}$

21. In the L R circuit shown in figure, switch S is closed at time t = 0, the charge that passes through the battery of emf E in one time constant is (e being the base of natural logarithm).

(a) $\frac{EL}{eR^2}$ (b) $\frac{EL}{eR}$

(c) $\frac{eER^2}{L}$ (d) $\frac{EL}{R}$



22. Natural Uranium is a mixture of $^{238}_{92}U$ and $^{235}_{92}U$ with a relative mass abundance of 140 : 1. The ratio of radioactivity contributed by the two isotopes of natural uranium, if their half-lives are 4.5×10^9 years and 7.0×10^8 years respectively is

(a) 99.3 : 0.7 (b) 50.3 : 49.7 (c) 95.6 : 04.4 (d) cannot be estimated

23. A cylinder of length ℓ > 1m filled with water ($\mu = \frac{4}{3}$) up to the brim, kept on a horizontal table is covered at its top by an equiconvex glass (μ = 1.5) lens of focal length 25 cm when in air. At mid day, 12.00 noon, Sun is just overhead and light rays comes parallel to the principal axis of the lens. The sun rays will be focused

(a) 25 cm behind the lens in the water (b) 37.5 cm behind the lens in the water
(c) 50 cm behind the lens in the water (d) 100 cm behind the lens in the water

24. Even the radiation of highest wave length in the ultraviolet region of hydrogen spectrum is just able to eject photoelectrons from a metal. The value of threshold frequency for the given metal is

(a) 3.83×10^{15} Hz (b) 4.33×10^{14} Hz (c) 2.46×10^{15} Hz (d) 7.83×10^{14} Hz

A - 2
ANY NUMBER OF OPTIONS 4, 3, 2 or 1 MAY BE CORRECT
MARKS WILL BE AWARDED ONLY IF ALL CORRECT OPTIONS ARE BUBBLED AND NO WRONG OPTION

25. A parallel plate capacitor of plate area A and plate separation d is charged to potential V. Then the battery is disconnected. A slab of dielectric constant k is then inserted between the plates of the capacitor so as to fill the space between the plates completely. If Q, E and W denote respectively, the magnitude of charge on each plate, the electric field between the plates (after the slab is inserted) and work done on the system, in question, in the process of inserting the slab, then

(a) $Q = k\varepsilon_0 AE$ (b) $Q = \frac{\varepsilon_0 kAV}{d}$ (c) $E = \frac{V}{kd}$ (d) $W = \frac{\varepsilon_0 AV^2}{2d}(1-\frac{1}{k})$

26. The magnitudes of the gravitational field at distances r_1 and r_2 from the centre of a uniform solid sphere of radius R and mass M are $F(r_1)$ and $F(r_2)$ respectively. Such that

(a) $\frac{F(r_1)}{F(r_2)} = \frac{r_1}{r_2}$ if $r_1 \le R$ and $r_2 \le R$

(b) $\frac{F(r_1)}{F(r_2)} = \frac{r_2^2}{r_1^2}$ if $r_1 \ge R$ and $r_2 \ge R$

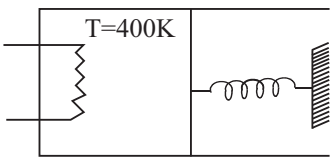
(c) $\frac{F(r_1)}{F(r_2)} = \frac{r_1}{r_2}$ if $r_1 \ge R$ and $r_2 \ge R$

(d) $\frac{F(r_1)}{F(r_2)} = \frac{r_1^2}{r_2^2}$ if $r_1 \le R$ and $r_2 \le R$

27. The intensity of sound at a point P is I_0, when the sounds reach this point directly and in same phase from two identical sources S_1 and S_2. The power of S_1 is now reduced by 64 % and the phase difference (ϕ) between S_1 and S_2 is varied continuously. The maximum and minimum intensities recorded at P are now I_{max} and I_{min} such that

(a) $I_{max} = 0.64\, I_0$ (b) $I_{min} = 0.36\, I_0$ (c) $\frac{I_{max}}{I_{min}} = 16$ (d) $\frac{I_{max}}{I_{min}} = \frac{16}{9}$

28. An ideal monatomic gas is confined within a cylinder by a spring loaded piston of cross-sectional area 4×10^{-3} m^2. Initially the gas is at 400 K and occupies a volume 2×10^{-3} m^3 and the spring is in its relaxed position. The gas is heated by an electric heater for some time. During this time the gas expands and the piston moves out by a distance 0.1 m. The spring connected to the rigid wall is massless and frictionless. The force constant of the spring is 2000 Nm^{-1} and atmospheric pressure is 10^5 Nm^{-2} then



(a) The final temperature of the gas is 720 K.
(b) The work done by gas in expanding is 50 J
(c) The heat supplied by heater is 190 J
(d) The heat supplied by heater is 290 J

29. A particle of mass m is located in a one dimensional potential field U (x) = U_0 (1 - cos ax); U_0 and a are constants. Which of the following statement/s is/are correct?

(a) The particle will execute Simple Harmonic Motion for small displacements.

(b) The stable equilibrium condition is $x = 0$

(c) The time period of small oscillations is $\frac{2\pi}{a}\sqrt{\frac{m}{U_0}}$

(d) The angular frequency for small oscillations is $\omega = a\sqrt{\frac{U_0}{m}}$

30. A ray of light is incident on an equilateral prism made of flint glass (refractive index 1.6) placed in air.

(a) The ray suffers a minimum deviation if it is incident at angle 53^0.

(b) The minimum angle of deviation suffered by the ray is 46^0.

(c) If prism is immersed in water ($\mu = \frac{4}{3}$) the minimum deviation produced by the prism is 14^0.

(d) The minimum deviation produced by the prism is 23.6^0 if it is immersed in a liquid of refractive index $\mu = 1.2$

31. In a p-n junction diode, the current (i) varies with applied biasing voltage (V) and can be expressed as $i = i_0\left(e^{qV/kT} - 1\right)$ where $i_0 = 5 \times 10^{-12}$ A is reverse saturation current, k is Boltzmann constant and q is the charge on the electron

At Absolute Temperature T = 300K

(a) The forward current is approximately 59.5 mA for a forward bias of 0.6 volt

(b) The current increases approximately by 2.75A if the biasing voltage changes from 0.6 V to 0.7 V

(c) The dynamic resistance of p-n junction is approximately 435 mΩ at the biasing voltage of 0.6 V

(d) The change in reverse bias current when biasing voltage change from -1 volt to -2 volt happens to be practically zero.

32. A charged oil (density 880 kg m^{-3}) drop is held stationary between two parallel horizontal metal plates 6.0 mm apart when a potential difference of V = 103 volt is applied between the two plates. When the electric field is switched off, the drop falls. At a certain time the drop is seen to fall a distance of 2.0 mm in 35.7 s and next 1.2 mm in 21.4 s. (The upper plate in the experiment is at higher potential).

Given that the viscosity of air = 1.80×10^{-5} Nsm^{-2} and density of air = 1.29 kg m^{-3}

(a) The radius of the drop is a = 7.25×10^{-7} m

(b) The charge on the drop is q = 8.0×10^{-19} C

(c) The terminal velocity of the oil drop, under its free fall, is 5.6×10^{-5} ms^{-1}

(d) The oil drop carries 5 excess electrons