INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2021

Day and Date of Examination : Sunday, January 24, 2021

Time : 10 AM to 1 PM

<u>Instructions to Candidates</u>

1. In addition to this question paper, you are given **answer sheet (OMR Sheet) for part A** and **answer paper for part B**.
2. On the answer sheet (OMR Sheet) for part A, fill up all the entries carefully in the space provided, **Only in block capital. Do write the name and PIN of your city.**

   Incomplete / incorrect / carelessly filled information may disqualify your candidature
3. On part A answer sheet, use only BLUE or BLACK BALL PEN for making entries and marking answers.
4. In Part A each question has **FOUR** alternatives. Any number of these (4, 3, 2 or 1) may be correct. You have to mark **ALL** correct alternatives and fill a bubble (●) for each, like

Q.No.	a	b	c	d
24	○	●	○	●

   Full marks are 6 for each question, you get them only when ALL correct answers are marked. The answers of part A shall be available on **www.indapt.org** on 1.2.2021.
5. Part A answer sheet will be collected at the end of one hour.
6. Any rough work should be done only on the sheets provided with part B answer paper.
7. Use of non-programmable calculator is allowed.
8. No candidate should leave the examination hall before the completion of the examination. You will take away the question paper with you.
9. Symbols used in the paper have their usual meaning unless specified otherwise.

PLEASE DO NOT MAKE ANY MARK OTHER THAN ● IN THE SPACE PROVIDED ON THE ANSWER SHEET OF PART A

Answer sheets for part A are to be evaluated with the help of a machine. Due to this, **CHANGE OF ENTRY IS NOT ALLOWED**

Scratching or overwriting may result in wrong score

DO NOT WRITE ANYTHING ON BACK SIDE OF ANSWER SHEET FOR PART A

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Part A- Maximum Marks: 150 Time for Part A : 60 minutes

Part B- Maximum Marks: 150 Time for Part B : 120 minutes

Part A

25x6 = 150

Mark the correct option/options (Any number of options may be correct).
Marks will be awarded only if all the correct options are marked. No negative marking.

1. The electric field $\vec{E}(\vec{r})$ in a certain region of space varies proportional to the position vector $\vec{r}$ as $\vec{E}(\vec{r}) = \alpha r$. The volume charge density for absulute premittivitiy (ε) in this region of space is

(a) $\rho = \alpha\varepsilon$

(b) $\rho = 2\alpha\varepsilon$

(c) $\rho = 3\alpha\varepsilon$

(d) $\rho = \alpha\varepsilon r$

2. A particle of mass'm' is dropped from a height h = R above the earth surface where R is the radius of the earth. If ΔE and v represent the loss of it potential energy and gain in its velocity of reaching the earth surface respectively then.

(a) $\Delta E = mgR$ and $v = \sqrt{gR}$

(b) $\Delta E = mgR$ and $v = \sqrt{2gR}$

(c) $\Delta E = \frac{mgR}{2}$ and $v = \sqrt{gR}$

(d) $\Delta E = \frac{mgR}{2}$ and $v = \sqrt{2gR}$

3. For a Vender Waal gas whose Vander Waal constants are a and b the

(a) Boyle temperature is $T_B = \frac{a}{Rb}$

(b) Temperature of inversion is $T_i = \frac{2a}{Rb}$

(c) Critical temperature is $T_C = \frac{8a}{27\,Rb}$

(d) Equation of stare for n mole is

$$\left(P + \frac{a}{V^2}\right)(V - b) = nRT$$

4. Knowing that $i = \sqrt{-1}$ the value of $(i)^i$ is/are

(a) non-zero

(b) imaginary

(c) sum of a non-zero real and a non-zero imaginary term

(d) real

5. A light flat rectangular steel strip of length $\ell = 1$m, breadth b = 3 cm and thickness d = 0.2 mm and negligible mass is hinged at one end so as to remain horizontal. A dimensionless block of mass M = 2 kg is loaded at free the end. Now the free end is slightly depressed and released so as the mass M to execute simple harmonic motion. Taking the geometrical moment of Inertia of the metallicslab as $I_g = \frac{bd^3}{12}$ and Young's modulus of its material as $Y = 2 \times 10^{11}$ Nm^{-2} The time period of small oscillations is

(a) $T = 2\pi\sqrt{\frac{4\,Ml^3}{Ybd^3}}$

(b) $T = 2\pi\sqrt{\frac{Ml^3}{2YI_g}}$

(c) $T = 2\pi\sqrt{\frac{Ml^3}{4YI_g}}$

(d) T = 66.2 s

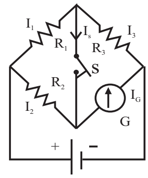
6. In the circuit shown if $R_1 \neq R_2$ and the reading in the galvanometer is the same with switch S open or closed. Which of the following is/are correct?

(a) $I_G = I_1$

(b) $I_G = I_2$

(c) $I_G = I_3$

(d) $I_G = I_2 + I_S$



7. Knowing that Lead (Pb) is fcc crystal with radius of atom r = 0.12 nm, estimate the number of atoms per square millimetre surface of (100) plane of Lead (Pb).
(a) 26.0×10^{12}
(b) 22.1×10^{12}
(c) 17.4×10^{12}
(d) 16.7×10^{12}

8. A LASER beam of wavelength 1.5 micron is used in a Michelson interferometer to obtain interference fringes. The fringes remained visible for a path length of 5.0 m. The lower limit on coherence time and spectral width respectively are
(a) 3.2×10^{-8} sec, 4.2×10^{-13} m
(b) 2.2×10^{-8} sec, 2.2×10^{-13} m
(c) 1.67×10^{-8} sec, 4.5×10^{-13} m
(d) 2.6×10^{-8} sec, 3.2×10^{-13} m

9. Pick up the correct option/s. The first time derivative of a
(a) vector of constant magnitude is always perpendicular to the vector itself.
(b) vector of constant direction is always perpendicular to the vector itself.
(c) vector of constant direction is always parallel to the vector itself.
(d) vector of constant magnitude is always parallel to the vector itself.

10. The isothermal compressibility for an ideal gas is defined as $K_T = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$
(a) The isothermal compressibility is = P (gas pressure)
(b) The isothermal compressibility is $=\frac{1}{P}$
(c) The adiabatic compressibility is $=\gamma P$
(d) The adiabatic compressibility is $=\frac{1}{\gamma P}$

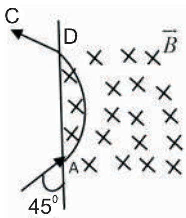
11. In a triclinic crystal, a lattice plane makes intercepts of length $a, \frac{b}{2}, 3c$ on the axes of x, y, z respectively. Miller indices of the plane are
(a) 163
(b) 136
(c) 361
(d) 326

12. Muons are elementary particles produced in the upper atmosphere and have a life time of τ = 2.2 μs. Muons are travelling vertically down towards the earth's surface at a speed of v = 0.998c. If for an observer on earth, the height of the atmosphere above the surface of earth is 10.4 km. Then which of the following statement(s) is/are true?
(a) The muons can never reach earth's surface
(b) The apparent thickness of the earth's atmosphere in muon's frame of reference is 0.96 km
(c) The lifetime of muons in earth's frame of reference is 34.8 μs.
(d) Muons travelling at a speed greater than 0.998c reach the earth's surface.

13. Mathematical formulation E = pc applies for
(a) electrons
(b) photon
(c) a mass less particle moving fast
(d) a particle moving with speed of light

14. In Fresnel's diffraction experiment
(a) the slit size is comparable to the wavelength of light used
(b) the source slit distance and the slit screen distance are comparable to the wave length of light
(c) diffraction grating cannot be used but zone plate is used
(d) the source size cannot largely exceed the slit size

15. A charged particle of charge q and mass m enters the region of magnetic field $\vec{B}$ with a velocity v at 45^0 from the straight boundary. After sometimes the particle comes out of the region at point D and goes along line DC.



(a) Inside the field region the charged particle moves in a circular path of radius $R=\frac{mv}{qB}$
(b) The straight distance AD is $=R\sqrt{2}$
(c) The time for which the particle is inside the region of magnetic field is $t=\frac{\pi m}{2qB}$
(d) If the direction of magnetic field $\vec{B}$ is reversed, the particle will never come out of the magnetic field region.

16. Consider a circular parallel plate capacitor of radius 'R' with separation 'd' between the plates (d<<R). The plates are placed symmetrically about the origin. If a sinusoidal voltage $V=V_0 \sin \omega t$ is applied between the plates, which of the following statement(s) is/are true?

(a) The maximum value of the Poynting vector at r = R is $\frac{\varepsilon_0 \omega R}{4d^2} V_0^2$

(b) The average energy per cycle flowing out of the capacitor is zero.

(c) The magnetic field inside the capacitor is constant.

(d) The magnetic field lines inside the capacitor are circular with the curl being independent of radius of circle (r).

17. The nuclear reaction $\pi^+ + n = \Delta^0 + K^+$

(a) Conserves isotopic spin

(b) Conserves strangeness

(c) Conserves Baryon number

(d) Is possible through strong interaction only

18. A photon of frequency υ, strikes an electron of mass 'm_0' initially at rest. After scattering at an angle ϕ, the Photon loses half of its energy? If the Electron recoils at an angle θ which of the following is / are correct?

(a) $\cos\phi = 1 - \frac{m_0 c^2}{h\upsilon}$

(b) $\sin\phi = 1 - \frac{m_0 c^2}{h\upsilon}$

(c) The ratio of magnitudes of the momenta of the recoiled electron and the scattered photon is $\frac{\sin\phi}{\sin\theta}$

(d) Change in the photon wavelength is $\Delta\lambda = \frac{h}{m_0 c^2}(1 - 2\cos\phi)$

19. An emitter follower often used as an impedance matching circuit has

(a) common emitter

(b) common collector

(c) both input and output in phase

(d) negative feedback gain less than 1

20. Which of the following has/have the dimensions of resistance (Ω)

(a) $\frac{L}{CR}$

(b) $\frac{E}{H}$

(c) $\frac{\mu}{\varepsilon}$

(d) $\frac{B}{D}$

Where all symbols have their usual meaning.

21. An alkaline solution has an absorption maximum near $4950 A^0$ and a fluorescence maximum at $5250 \overset{0}{A}$. The energy lost in the process of absorption and re-emission of one quantum is

(a) 1.98×10^{-20} J

(b) 2.30×10^{-20} J

(c) 1.38×10^{-16} J

(d) 3.89×10^{-14} J

22. A star Alpha-Centauri initially has 10^{40} deuterons. In the star, the energy is produced via the process ${}_1^2H + {}_1^2H \longrightarrow {}_1^3H + {}_1^1H$ and ${}_1^2H + {}_1^3H \longrightarrow {}_2^4He + {}_0^1n$ where the Mass $({}_2^4He) = 4.001u$, Mass $({}_1^2H) = 2.014u$, Mass $({}_1^1H) = 1.007u$, Mass $({}_0^1n) = 1.008$ u, If the average power radiated by the star is 10^{16} watt, the deuteron supply of the star is exhausted in a time of the order of

(a) 365 days

(b) 1.3×10^{12} second

(c) 4.1×10^4 year

(d) 3.15×10^7 second

23. The dominant mechanism for the motion of current carriers in a forward and reverse biased Silicon p-n junction diode are

(a) Drift in forward bias and diffusion in reverse bias

(b) Diffusion in forward bias and drift in reveres bias

(c) Diffusion in both forward and reverse bias

(d) Drift in both forward and reverse bias

24. The uncertainty in the position of an electron in its orbit hydrogen atom is given as $0.5A^0$. If r and Δp denote the radius and the uncertainty in the linear momentum of electron in the second Bohr orbit respectively. Then

(a) $r = 2.0\ A^0$ and $\Delta p = \frac{h}{\pi} \times 10^{10}$

(b) $r = 2.0\ A^0$ and $\Delta p = \frac{h}{2\pi} \times 10^{10}$

(c) $r = 1.0\ A^0$ and $\Delta p = \frac{h}{\pi} \times 10^{10}$

(d) $r = 1.0\ A^0$ and $\Delta p = \frac{h}{2\pi} \times 10^{10}$

25. In a uniformly doped abrupt p-n junction, the doping level on n-side is four times of that at p-side. If the depletion layer width and the diffusion length across the junction diode are denoted by x and L respectively, then choose the correct option (s)

(a) $\frac{x_n}{x_p} = \frac{2}{1}$ and $\frac{L_n}{L_p} = \frac{1}{2}$

(b) $\frac{x_n}{x_p} = \frac{1}{2}$ and $\frac{L_n}{L_p} = \frac{2}{1}$

(c) $\frac{x_n}{x_p} = \frac{1}{2}$ and $\frac{L_n}{L_p} = \frac{\sqrt{2}}{1}$

(d) $\frac{x_n}{x_p} = \frac{\sqrt{2}}{1}$ and $\frac{L_n}{L_p} = \frac{1}{2}$

Part B1   10x5 = 50

Answer all the following in brief (not more than 10 lines) with appropriate reasoning

B1. Microwaves are the electromagnetic radiations of wave length of the order of micrometer ($\lambda = 10^{-6}$m) in free space. Defend or refute.

B2. A flat sheet of glass (refractive index =1.5) is coated with a transparent material (refractive index = 1.25) with negligible thickness so that the light of wavelength 6000 A^0 (in vacuum) is not reflected at all. Defend or refute.

B3 It is necessary to rotate the apparatus / interferometer in Michelson Morley experiment to conclude its results. Defend or refute with appropriate reasoning.

B4. A diffraction grating with 8000 line per inch can exhibit diffraction upto fifth order when the wavelength of light is 625 nm. Defend or refute.

B5. The difference in the speed of the O-ray and E-ray in a uniaxial crystal is maximum in a direction perpendicular to the optic axis. Defend or refute.

B6. Distinguish between the precessional frequency and cyclotron frequency of proton moving in a perpendicular magnetic field.

B7. In order to get a Billiard ball of radius R to roll without sliding from start, the ball must be hit exactly $\frac{2}{5}$ R above the centre line.

B8. The luminosity of a rigid star in Orion constellation is 17000 times that of the Sun. The temperature of the rigid star is nearly 66000 K. Defend or refute.

B9. The fermi energy (E_f) of electron gas in a metal does not depend on size / Volume of the specimen however, it does depends on molecular concentration Justify.

B10. Design a logic circuit using basic logic gates with three inputs A,B,C such that the output Y goes to a low Logical value when A is high Logical value while the B and C are in different levels.

Part B2 — $10x10 = 100$

Solve all the 10 problems. Each carries 10 marks.

P1.(a) Show that the acute angle between the diagonals of a cube is $\theta = \cos^{-1}\left(\frac{1}{3}\right)$

(b) Find the angular velocity $\vec{\omega}$ of a particle of mass m = 2 kg moving round in a circle with velocity $\vec{v} = 3\hat{i} - 4\hat{j} + 5\hat{k}\ ms^{-1}$ in terms of unit vectors $\hat{i}, \hat{j}$ & $\hat{k}$ when the radius vector is $\hat{r} = \hat{i} + 9\hat{j} - 8\hat{k}$ m. Also find its angular momentum at the same instant.

P2. Elaborate the concept of mechanical impedance of a mechanical oscillator subjected to a periodic force. What is the physical significance of mechanical impedance? Discuss the condition of resonance in a mechanical system.

P3. A real gas obeys an equation of state given by $P(V - nb) = nRT$ where n is the number of moles of the gas. Its heat capacity at constant volume is given by $C_v = n\,[C_0 - C_1T]$ where C_0 and C_1 are constants, and T is the absolute temperature. In a process, one mole of gas at a temperature T_1 and volume V_1 is heated at a constant pressure P_1 up to a temperature T_2 ($>T_1$). Determine

(a) The constant R and the final volume V_2

(b) The work done by the gas in this process.

(c) The heat supplied to the gas during this process.

(d) The net change in the entropy of the gas during this process

P4. Show that the energy flux (Energy flowing per second per unit area of cross-section) in a plane polarised electromagnetic wave, in free space, is the energy density times the wave velocity.

P5. Diffraction of a collimated beam of white light at N parallel equidistant slits in a plane (a plane transmission diffraction grating) provides intensity.

$$I = \left(\frac{A \sin \alpha}{\alpha}\right)^2 \left(\frac{\sin N\beta}{\sin \beta}\right)^2$$

Discuss the general variation of intensity on a distant screen. Explain the formation of spectra and obtain an expression for dispersive power of this system.

P6. A point object of mass m and charge q moving with velocity $v_o\hat{i}$ along x-axis, enters a magnetic field $B_o\hat{k}$. Determine

(a) The magnetic flux enclosed by the orbit of the particle

(b) The angular momentum (L) of the orbital motion of the particle and its magnetic dipole moment (μ)

(c) The ratio $\frac{\mu}{L}$

P7. Consider a quantum particle of mass m confined to the region $0 < x < L$ in a one dimensional potential well. If $\phi_0(x)$ and $\phi_1(x)$ are the normalised eigen functions of the ground state and the first excited state respectively, and if the wave function of the particle at t = 0 is

$$\Psi(x) = \frac{1}{\sqrt{2}}\{\phi_0(x) + \phi_1(x)\}$$

Determine the average energy of the particle.

P8. (a) Using the values $hc = 197.3386$ MeV × fm, Electron charge $e = 1.602 \times 10^{-19}$C and $\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9$ SI units. Find

(i) the value of $\frac{e^2}{4\pi\varepsilon_0}$ in units of MeV fm

(ii) the value of the fine Structure constant α.

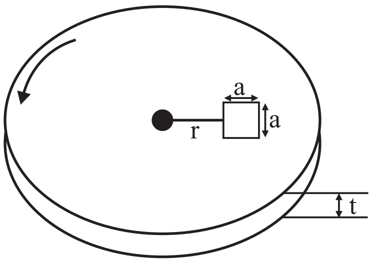
Also express $\frac{1}{\alpha}$ in pure numeric.

(b) Eight distinguishable particles are distributed in two compartments. The first compartment is divided into 4 cells and the second into two cells. Each cell is of equal a priori probability and there is no restriction on the number of particles that can be contained in each cell. Calculate the thermodynamic probability of

(i) the most probable state and

(ii) the macro state (8,0)

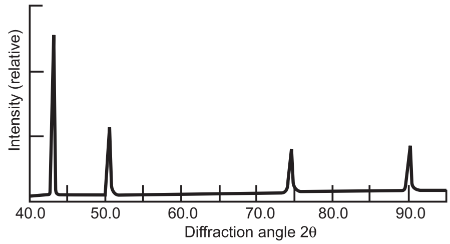
P9. An electromagnetic "eddy current" brake consists of a circular disk of conductivity σ and thickness t. It is rotating about an axis through its centre with a magnetic field $\vec{B}$ applied perpendicular to the plane of the disk over a small area a^2.



If the area a^2 is at a distance r from the axis of rotation, find an approximate expression for the torque tending to slow down the disk at the instant its angular velocity equals to ω.

P10.(a) Given that the two solution of the quadratic equation $x^2 - 10x + 31 = 0$ are $x = 5$ and $x = 8$. What is the base of the numbers?
The base of numbers in the decimal system in normal use is 10.

(b) The first four peaks of the x-ray $\lambda = 0.154$ nm diffraction pattern for copper which has a FCC crystal structure are found to be at Angle $2\theta_1 = 43.8^0$, $2\theta_2 = 50.8^0$, $2\theta_3 = 74.4^0$ and $2\theta_4 = 90.4^0$.



For each of these peaks, find
(a) Index (h, k, l)
(b) The interplanar spacing
(c) The atomic radius for Cu.