INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2020

Day and Date of Examination : Sunday, January 19, 2020

Time : 10 AM to 1 PM

Instructions to Candidates

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.in** on 1.2.2020.
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

25 x 6 = 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.

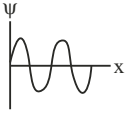
1. The position vector of a particle of mass m is expressed as $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. The value of $\vec{\nabla}.\vec{r}$ is
   a) 0
   b) $\frac{1}{r}$
   c) $\frac{2}{r}$
   d) $\frac{3}{r^2}$

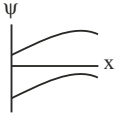
2. An infinitesimal volume element in cylindrical coordinate system is
   a) $d\tau = s^2\, ds d\varphi dz$
   b) $d\tau = \varphi ds d\varphi dz$
   c) $d\tau = z ds d\varphi dz$
   d) $d\tau = s ds d\varphi dz$

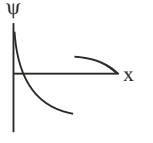
3. An electric field defined in a certain region is given by $\vec{E}(x,y,z) = ax\hat{i} + cz\hat{j} + 6by\hat{k}$. The set of values of parameters a, b and c that permits $\vec{E}(x,y,z)$ to be a valid electric field is / are
   a) 13, 1, 12
   b) 17, 6, 1
   c) 13, 1, 6
   d) 45,6,1

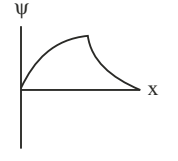
4. In a Newton's ring experiment, the plano-convex lens of radius R is kept on to a plane glass plate to obtain a central dark spot surrounded by concentric bright and dark rings. When the lens is raised vertically up by a distance 'h' without disturbing the set up, one thousand fringes emerge out of the centre and the central spot is still dark. The wavelength (λ) of the light used is
   a) $\lambda = h$
   b) $\lambda = h/5$
   c) $\lambda = h/500$
   d) λ cannot be determined by the given data

5. Acceptable wave function (s) to represent the quantum state of a physical system is/are

   a) 

   b) 

   c) 

   d) 

6. If $\vec{A}$ is the magnetic vector potential, the value of $\oint \vec{A}.\vec{dl}$ is equal to
   a) 0 (Zero)
   b) Electric flux (ϕ_E)
   c) Magnetic flux (ϕ_B)
   d) Magnetic induction ($\vec{B}$)

7. An electron propagating along the x-axis passes through a silt of width Δy = 1nm. The uncertainty in the y-components after passing through the slit is
   a) $(\Delta p_y)(\Delta y) \sim \hbar$; 1.06×10^{-25}kgm/sec
   b) $(\Delta p_x)(\Delta x) \sim \hbar$; 7.32×10^{-25}kgm/sec
   c) $(\Delta v_y)(\Delta y) \sim \hbar/m$; $1.16\ 10^5$m/sec
   d) $(\Delta v_x)(\Delta x) \sim \hbar/m$; $7.32\ 10^5$m/sec

8. A hollow spherical shell as shown carries charge density $\rho = \frac{k}{r^2}$ in the region. $a \le r \le b$

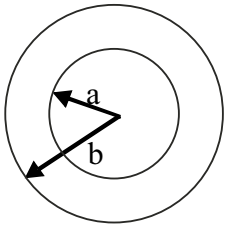
The electric field in the region ($r \ge b$) is

a) $\vec{E} = \frac{k(r - a)}{\varepsilon_0 r^2}\hat{r}$

b) $\vec{E} = \frac{k(b - a)}{\varepsilon_0 r^2}\hat{r}$

c) $\vec{E} = \frac{k(b - a)}{\varepsilon_0 r^2}\hat{\theta}$

d) $\vec{E} = \frac{k(r - a)}{\varepsilon_0 r^2}\hat{\theta}$



9. A square plate of uniform thickness and side 'a' has its centre O at the point of intersection of the two diagonals AC and BD. A quarter of the plate is cut and removed so that the remainder looks like the shape in the Fig. 2

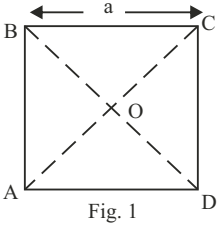


Fig. 1

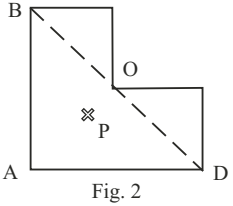


Fig. 2

The centre of mass of this shape moves to P along the diagonal OA. The distance OP is

a) $\frac{a}{6\sqrt{2}}$

b) $\frac{a}{3\sqrt{2}}$

c) $\frac{a}{\sqrt{3}}$

d) $\frac{a}{\sqrt{2}}$

10. In an experiment with plane transmission diffraction grating with N parallel slits using monochromatic light, a number of principal maxima is observed. The intensity at the principal maximum

a) increases with the order of diffraction
b) decreases with the order of diffraction
c) is the same for all orders of diffraction
d) is proportional to N^2 in a particular order

11. A particle is released from $x = 1$ in a force field $F(x) = \left(\frac{1}{x^2} - \frac{x^2}{2}\right)\hat{i}$, for $x \ge 0$ which of the following statement(s) is/ are true?

a) $\vec{F}(x)$ is conservative.
b) $\vec{F}(x)$ is non-conservative.
c) The particle moves towards $x = \sqrt{2}$
d) The particle moves towards the origin.

12. A plane polarised light is passed through a quarter wave plate $\left(\frac{\lambda}{4}\text{ plate}\right)$. The emergent light

a) is elliptically polarised light
b) may be elliptically polarised light
c) may be circularly polarised light
d) may be plane polarised light

13. A sample of magnetic material is kept in the region of a magnetic field. The magnetic field is suddenly withdrawn under adiabatic conditions. The change in temperature is observed due to

a) Magnetic component of entropy
b) Lattice component of entropy
c) Phononic component of entropy
d) Vibrations of atoms about their mean position

14. Meissner effect can be used to distinguish between

a) metal and insulator
b) metal and semiconductor
c) superconductor and perfect metal
d) superconductor and insulator

15. The density of state changes with energy in nano rods as

a) E^0
b) $E^{\frac{1}{2}}$
c) $E^{-\frac{1}{2}}$
d) $E^{\frac{3}{2}}$

16. Two systems with heat capacities and entropies c_1, S_1 and c_2, S_2 respectively, interact thermally and come to a common temperature T_f. If the initial temperature of the system one was T_1, what were the initial temperature of system two (T_2) and net change in entropy (Δs) of combined system? You may assume that the total energy of the combined system remains constant.

a) $T_2 = \frac{C_1}{C_2}(T_f - T_1) + T_f$

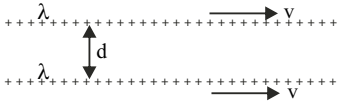
b) $T_2 = \frac{C_1}{C_2}(T_f - T_1) - T_f$

c) $S = In\left[\frac{T_2^{C_2}}{T_1^{C_1}} \cdot T_f^{C_1 - C_2}\right]$

d) $S = In\left[\frac{T_2^{C_2}}{T_1^{C_1}} \cdot T_f^{C_1 + C_2}\right]$

17. Two linear simple harmonic motions of equal amplitude, and frequency ω and 2ω along perpendicular directions of axes of X and Y respectively are impressed on a particle. If the initial phase difference between them is $\frac{\pi}{2}$, the resultant path followed by the Particle is
a) straight line
b) circle
c) parabola
d) ellipse

18. Two identical line of charge (charge per unit length λ) are moving parallel to each other at a separation d with velocity v. The value of v for which the electrostatic force of repulsion is completely compensated by magnetic attraction between them is



a) $v = \frac{c}{2}$

b) $v = \frac{c\sqrt{3}}{2}$

c) $v = \frac{1}{\sqrt{2}}c$

d) $v = c$

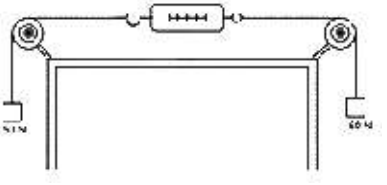
19. In the Kronig-Penney model, electrons are assumed to be moving in
a) one-dimensional square well potential
b) one-dimensional square well periodic potential
c) three-dimensional coulomb potential
d) a periodic harmonic potential

20. The ground state energy of a particle in an one-dimensional quantum well is 4.4 eV. If the width of the well is doubled, then the new ground state energy is
a) 1.1eV
b) 2.2eV
c) 8.8eV
d) 17.6Ev

21. Property (ies) of first order transition is /are
a) discontinuity in entropy
b) discontinuity in volume
c) discontinuity in derivative of Gibb's free energy
d) involvement of Latent heat

22. The distinction between Fermi-Dirac (FD) and Bose- Einstein (BE) distribution arises due to
a) Spin
b) Pauli exclusion principle
c) Indistinguishability
d) Wave function

23. A spring balance is stretched horizontally over a table by strings going over pulleys attached to table edges, and hanging 50 N weights. The reading on the balance in equilibrium is



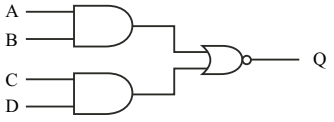
a) 100 N
b) 50 N
c) 25 N
d) 0

24. Fourier series of a given function f(x) in interval 0 to L is given

$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos\frac{n\pi x}{L} + \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{L}$

then find the value of b_2 for f(x) = x, in the region (0,L)
a) L/2π
b) L/π
c) 2L/π
d) 4L/π

25. The Boolean equation of the circuit diagram shown below is



a) $Q = \overline{A.B + C.D}$

b) $Q = \overline{(A + B)}.\overline{(C + D)}$

c) $Q = (\overline{A + B}).(\overline{C + D})$

d) $Q = A.B + C.D$

Part B_1 10x5 = 50

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

B1. Imagine that by some grand feat of technology it becomes possible to create a perfectly uniform magnetic field (in z-direction) in a perfectly cubical region (with edges parallel to the x, y, z, axes). Is it possible to shoot a charged particle from outside this region into this magnetic field such that upon entry the particle remains confined to the region? If yes, how can this be done, and if no, why not?

B2 Electromagnets are used by cranes to hold, pickup, and move heavy metallic loads. This implies that magnetic forces can be used to do work. Defend or Refute.

B3 The radius vector of a planet sweeps out equal area in equal intervals of time. This is consistent with the conservation of angular momentum of the planet. Defend or Refute.

B4. Steel is more elastic than rubber, Defend/Refute

B5. A zone plate exhibits focusing action like a convergent lens but has multiple foci unlike the convex lens. Defend or refute.

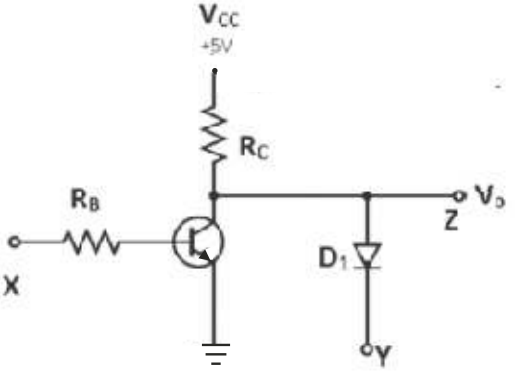
B6. A beam of plane polarised light is made incident normally on a quartz plate wtih faces cut parallel to the optic axis. If the plane of vibration of the incident beam is inclined at 30^0 with the optic axis, the ratio of intensities of ordinary and extraordinary rays, is found to be 1:3. Defend or refute.

B7. The minimum uncertainty in the energy of a hydrogen atom, if an electron remains in the exited state for 10^{-8} sec, is 3.3 ev. Defend or refute.

B8. The total energy of a moving particle is found to be much larger than its rest energy. Its de-Broglie wave length is equal to the wavelength of a photon of identical energy. Defend or refute.

B9. Neutrons can be slowed down, even by ordinary water which have Hydrogen-nuclei (^1_1H) having mass almost equal to that of neutrons. Still heavy water is used for this purpose in a reactor. Explain why?

B10. In the given circuit, the transistor has negligible collector – to – emitter saturation voltage and diode drops negligible voltage across it under forward bias. If V_{cc} is +5 volt, X & Y are digital signals with 0V and V_{cc} as logic 1, then the Boolean expression for Z as output is..... Write the expression by filling up the gap.



Part B_2 10x10 = 100

Solve all the 10 problems. Each carries 10 marks.

P1. (a) The half-life of a sample of Ra^{226} is 1620 years, how many number of atoms decay in one second in 1gm sample of Ra?

(b) The amount of drug dissolved in the body is proportional to the amount present in the capsule, If 30% of 500 mg is dissolved in 1 hour, calculate the time taken to dissolve 450 mg.

P2. Knowing that $\int_A^B \vec{F}.\vec{dl}$ is regarded as the work done in moving a particle from A to B, evaluate the work done by the force $\vec{F} = 2xy\hat{i} + (x^2 - z^2)\hat{j} - 3xz^2\hat{k}$ N in moving a particle of mass m = 2kg from A (0,0,0) to B (2m,1m,3m) when the motion is restricted along a straight line.

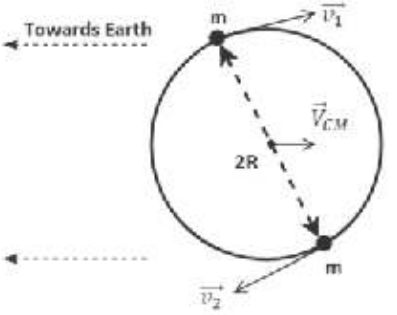
P3. When a surface is irradiated with light of wavelength $\lambda = 4950\ A^0$, a photo-current appears which vanishes if a retarding potential greater than 0.6V is applied across the photo-tube. When a different source of light is used, it is found that the critical retarding potential is changed to 1.1V. Find the work function of the emitting surface and the wavelength of the second source. If the photo-electrons (after emission from the surface) are subjected to a perpendicular magnetic field of 10 tesla, what changes will be observed in the above two retarding potentials?
$(h = 6.63 \times 10^{-34}\ J\text{-}s, c = 10^8\ m/s, e = 1.6 \times 10^{-19}\ C)$

P4. A current distribution gives rise to a vector potential $\vec{A} = x^2 yi + y^2 xj - 4xyzk\ \frac{Wb}{m}$ calculate

a) the magnetic induction $\vec{B}$ at a point P(−1,2,5)

b) the magnetic flux-through the surface defined by $(0 \le x \le 1, -1 \le y \le 4, z = 1)$

P5. The figure shows a binary star system with its orbital plane containing the line of view from the Earth.



The system is a spectroscopic binary and light from it received on the Earth shows measurable Doppler shift. A hydrogen line corresponding to 4.568110×10^{14} Hz frequency in the laboratory, shows Doppler shifted frequency ranging from $f_{min} = 4.567710 \times 10^{14}$ Hz to $f_{max} = 4.568910 \times 10^{14}$ Hz in the light received from the binary. The time between two successive observations in which f_{max} is recorded is 11 days. Find

a) Velocity $\vec{V}_{CM}$ of centre of mass of the binary,

b) Speed v of either star on the circular orbit,

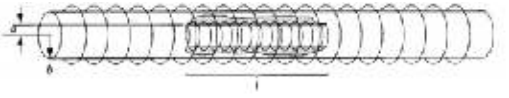
c) Radius R of the common circular orbit and

d) The common mass of the stars.

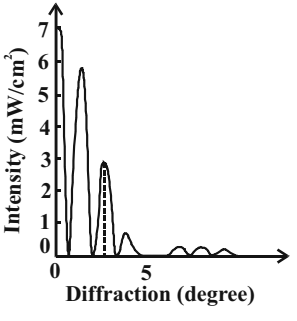
$(G = 6.674 \times 10^{-11})$. The Doppler shift for electromagnetic waves is given by $f = f_0\left(1 - \frac{u}{c}\right)$ where u is the speed of the source away from a stationary observer.

P6. Explain the terms 'line-width' and 'frequency spread' for a spectral line obtained from a LASER. One of the most prominent line of Krypton (orange) is $\lambda = 6058\ A^0$ with the coherence length L = 20 cm. Calculate the line-with and the coherence time.

P7. Explain the terms self and mutual inductance. Write expressions for self and mutual inductance. A short solenoid (length l and radius a, with n_1 turns per unit length) lies on the axis of a very long solenoid (radius b, n_2 turns per unit length) as shown in figure. Current i flow in the short solenoid. Calculate the flux through the long solenoid. Also find mutual inductance between the two coils.



P8. Write down expression for the intensity for double slit diffraction. What do you mean by missing order in double slit diffraction pattern? Light of wavelength 440 nm passes through a double slit, yielding the diffraction pattern of intensity I verses diffraction angle as shown in the figure. Calculate width of each slit and slit separation.



P9. A piece of N-type Silicon of length L=10 μm has a cross sectional area A=0.001cm^2. A voltage 10V is applied across the sample yielding a current I = 100 mA. Calculate the resistance, conductivity & electron density of sample if the electron mobility $\mu_n = 1400\ cm^2/V\text{-sec}$.

P10. Analyse the circuit given in figure and determine I_c and V_{CE}. Given that $V_{BE} = 0.7$ V and $\beta = 200$.