INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2019

Day and Date of Examination : Sunday, 20th January 2019

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 1.2.2019.
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

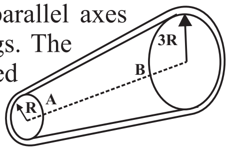
25 x 6 = 150

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. If the area $\vec{S}$ encloses volume V and the curve c binds the area $\vec{S}$ then
(a) $\iiint_V (\vec{\nabla}.\vec{E})dV = \oint_S \vec{E}.d\vec{S}$ is Gauss divergence theorem.
(b) $\iint_S (\vec{\nabla}\times\vec{B}).d\vec{S} = \oint_c \vec{B}.d\vec{l}$ is Stoke's theorem.
(c) $\oint_c \vec{E}.d\vec{l} = -\frac{\partial}{\partial t}\iint_S \vec{B}.d\vec{S}$ denotes Faraday's law of electromagnetic induction.
(d) $\oint_c \vec{B}.d\vec{l} = \mu_0 \iint_S \left[\vec{J} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t}\right].d\vec{S}$ is modified Ampere's law.

2. If f (r) is a scalar function of position, the expression $\vec{\nabla}\times f(r)\hat{r}$ is evaluated to have a value
(a) = +1
(b) = −1
(c) = 0 (zero)
(d) depending upon the form of the function f(r)

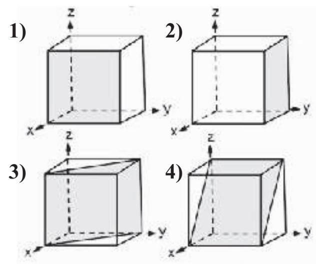
3. Two circular wheels A and B of radii R and 3R are mounted on fixed parallel axes with frictionless bearings. The two wheels are connected through a common belt running over them without slipping.



The ratio of their moments of inertia $\frac{I_A}{I_B}$ is
(a) $\frac{1}{3}$ if they have equal angular momentum
(b) $\frac{1}{9}$ if they have equal angular momentum
(c) $\frac{1}{3}$ if they have equal kinetic energy
(d) $\frac{1}{9}$ if they have equal kinetic energy

4. Identify the differential equation(s) of forced oscillations.
(a) $m\frac{d^2x}{dt^2} + Kx = 0$
(b) $m\frac{d^2x}{dt^2} + r\frac{dx}{dt} + Kx = 0$
(c) $m\frac{d^2x}{dt^2} + r\frac{dx}{dt} + Kx = F_0 \sin pt$
(d) $L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = \omega E_0 \cos \omega t$

5. Which of the following figures show(s) the (101) crystal plane of a cubic lattice?



(a) Figure 1)
(b) Figure 2)
(c) Figure 3)
(d) Figure 4)

6. In a Betatron, the electrons are accelerated
(a) by the principle of resonance
(b) by the principle of induction
(c) for one-fourth of the period of applied AC voltage
(d) for one-half of the period of applied AC voltage

7. Quantum mechanically acceptable wave function(s) over the domain $-\infty \leq x \leq +\infty$ is/are (where x_0 defines a fixed location within the specified domain on the x-axis).

(a) $f(x) = \dfrac{1}{x - x_0}$

(b) $f(x) = \exp\left(-\dfrac{|x|}{x_0}\right)$

(c) $f(x) = \exp(-x^2)$

(d) $f(x) = \exp(+x)$

8. When a photon stimulates the emission of another photon, the two photons have

(a) same phase

(b) same energy

(c) same direction

(d) same wavelength

9. In a Ruby LASER

(a) the active element is Aluminium

(b) the active element is Chromium

(c) the monochromatic light emitted is green

(d) the monochromatic light emitted is red

10. Consider a closed metallic surface S enclosing the region R, which is vacuum. Within the space around, the electric potential is denoted by V and the electric field by E. Then one can say that,

(a) V is uniform on the surface S

(b) V is uniform on the surface S only if there are no free charges outside S.

(c) E is zero in region R, only if there are no free charges in this region R.

(d) V is uniform in region R, only if there are no charges on the surface S.

11. If a particle is represented by a wave of sharply defined single wave length λ then

(a) its momentum is completely uncertain

(b) its position is completely uncertain

(c) its frequency is completely uncertain.

(d) its velocity is completely uncertain

12. A square table of sides of length L and mass M distributed uniformly has four light legs not at its corners but at centres of its sides. A mass m can be kept anywhere on the table. The maximum value of m, for which the table will not topple, no matter where m is kept, is

(a) $M\sqrt{2}$

(b) $2M$

(c) $\dfrac{M}{2}$

(d) M

13. According to the concept of space quantisation of vector atom model, the possible orientations of the total angular momentum vector $\vec{j}$ for $j = \dfrac{3}{2}$ with respect to a given magnetic field B = 1.2 tesla may be

(a) $\theta = 0^0$

(b) $\theta = 39.2^0$

(c) $\theta = 75.0^0$

(d) $\theta = 150.0^0$

14. In a thermodynamical system at constant temperature and constant pressure

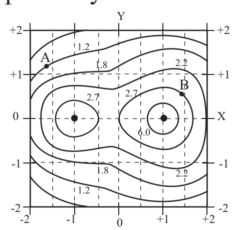
(a) Gibbs free energy tends to a minimum

(b) Gibbs free energy tends to a maximum

(c) Helmholtz free energy tends to a minimum

(d) Helmholtz free energy tends to a maximum

15. The figure shows equipotential contours for two charges located along the X-axis. Two points A and B have been marked on 1.2 volt and 2.7 volt contours respectively. Choose the correct statement(s)



(a) The charges are in the ratio 1 : 3.

(b) Both the charges are positive.

(c) Potential energy of a negative charge increases when moved from point A to point B

(d) On X-axis (y = 0), the field is zero some where between x = −1 and x = +1.

16. The electronic configuration of ground state of Nitrogen (N) is $1s^2\,2s^2\,2p^3$ and that of Oxygen (O) is $1s^2\,2s^2\,2p^4$. Hence

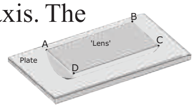
(a) the parity of Nitrogen is even

(b) the parity of Nitrogen is odd

(c) the parity of Oxygen is even

(d) the parity of oxygen is odd

17. Suppose a right circular solid glass cylinder is cut by a plane parallel to its axis. The resulting 'lens' is placed on an optically plain glass plate as shown in the figure.



A Newton's rings type interference experiment is now performed. The interference fringes seen

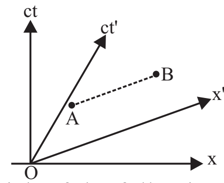
(a) will be elliptical with major axis parallel to AB and of non-uniform width.

(b) will be straight, parallel to AB and of non-uniform width.

(c) will be straight, parallel to AD and of uniform width.

(d) will be straight, parallel to AB and of uniform width. b

18. An inertial frame S' is moving towards the positive X–direction relative to another inertial frame S. In the given figure two events A and B are represented in the respective space time diagrams of S and S'. Which of the following is/are correct statement (s)



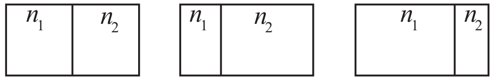
(a) A and B are simultaneous events in S

(b) A and B are simultaneous events in S'

(c) The axis O-ct' is also world line of the moving particle in S-frame

(d) A and B are co-local in both S and S'

19. Two samples of an ideal gas are contained, on two sides, in a cylinder with rigid conducting walls and a movable conducting partition as shown in figure for three different positions of the partition, with n_1 number of molecules on the left and n_2 molecules on the right such that $n_1 > n_2$. In the first case the partition is exactly in the middle of the cylinder while in the second case it is shifted to left side and in the third case it is shifted to the right side. The free energy of the thermodynamical system is



(a) least in the first case.

(b) least in the second case.

(c) least in the third case

(d) equal in all the three cases

20. The correct statement(s) about a p-n junction diode is/are:

(a) There is absolutely no current flow across the diode when it is reverse biased.

(b) The current flow across a diode is quite significant as soon as it is forward biased (say ~ 10 μV).

(c) The current flow across the diode is significant only when diode is forward biased say by 1 V or larger.

(d) The variation of current against voltage (I v/s V) in forward biased condition is exponential.

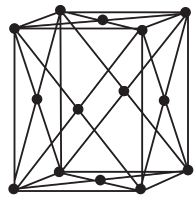
21. The given unit cell of a crystal system may be lebelled as

(a) Body centred tetragonal lattice.

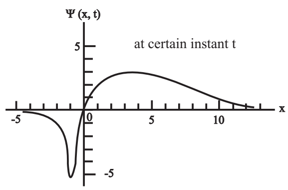
(b) Face centred orthorhombic lattice.

(c) Base centred monoclinic lattice.

(d) Primitive unit cell.



22. At a certain instant of time t, the position dependent wave function Ψ(x,t) of a particle is plotted against position (x) at a certain instant as shown



(a) The particle is more likely to be found in the region $x > 0$

(b) The particle is more likely to be found in the region $x < 0$

(c) The particle is least likely to be found at the origin

(d) The particle is most likely to be found at x=4

23. The hyperfine splitting of atomic spectral lines is due to interaction between

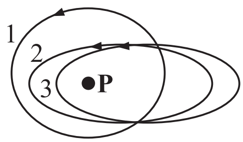
(a) the magnetic moments due to orbital motion and the spin of valence electrons.

(b) an external magnetic field and the spin magnetic moment of the valence electron

(c) the magnetic moments of the electron and the nucleus

(d) the external electric field and the electric quadrupole moment of the nucleus.

24. The three orbits of a satellite around the same planet P shown have the same major axis 'a' but different eccentricity $\left(e=\frac{b}{a}\right)$. If E_1, E_2 and E_3 are the energies of the satellite in the three orbits while T_1, T_2 and T_3 are the respective time periods, then



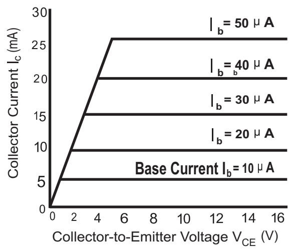
(a) $E_1 > E_2 > E_3$

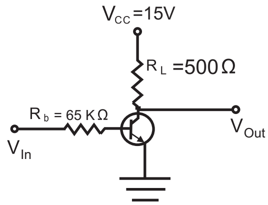
(b) $E_1 = E_2 = E_3$

(c) $T_1 > T_2 > T_3$

(d) $T_1 = T_2 = T_3$

25. A transistor is connected in CE mode. The output characteristics of the transistor are shown graphically. The input voltage is V_{in}=2V, and the voltage drop across emitter-base junction is 0.7 V,





(a) the base current in the circuit is $I_b = 20\,\mu A$

(b) the collector current is $I_c = 10$ mA

(c) the output voltage $V_{CE} = 10V$

(d) the DC current gain is $\beta = 500$

Part B_1 — 10x5 = 50

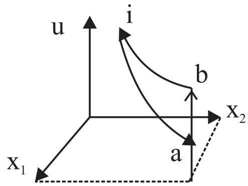
Answer all the following in brief (not more than 10 lines) with appropriate reasoning

B1. Speed of sound in a gas can not be greater than the r.m.s speed of the molecules of the gas at same temperature. Defend or refute.

B2. The magnetic field on the axis of a tightly wound long solenoid is $B = \mu_0 ni$ where n is the number of turns per unit length. This suggests that the magnetic field does not depend upon the total length of the solenoid and hence if one adds some more loops at the end keeping the n as same, the field does not increase. Defend or refute.

B3. The total displacement current at any instant t through an ideal parallel plate capacitor in a series C−R circuit fed by a time-varying voltage V(t) equals the current i(t) through the resistor at the same instant. Defend or refute.

B4. Consider a system described by three state variables internal energy U and two other variables x_1 and x_2. A physicist wants to take the system through a cyclic process i→a→b→i as shown. The process i→ a and b→i are both adiabatic. In the process a→b varibles x_1 and x_2 do not change however heat Q is transferred and no work is done. All the three processes are reversible. The complete cyclic process is in agreement with the second law of thermodynamics. Defend or refute



B5. In a interference experiment, the geometrical path difference responsible for observable fringes is smaller than the coherence length for the of light used. Defend or refute.

B6. The Fermi energy of a system of 2N electrons confined in a one dimensional infinite potential well of width 'a' is $\frac{N^2\pi^2\hbar^2}{2ma^2}$. Defend or Refute with suitable explanation.

B7. The half life of the decay of radioactive carbon $\left({}_{6}C^{14} \rightarrow {}_{7}N^{14} + {}_{-1}\beta^{0}\right)$ is $T_{1/2} = 5730$ years. The equilibrium mass ratio $\frac{{}_{6}C^{14}}{{}_{6}C^{12}} = 1.3 \times 10^{-12}$ in the natural carbon as found in living organic matter. The decay rate of 4 gram of natural carbon is 1 disintegration per second. Defend or refute.

B8. Huygen's eyepiece is used in the Fresnel's biprism experiment to observe interference fringes. Defend or refute.

B9. In $\alpha-$ decay of a nucleus of mass number A at rest, the daughter nucleus has an mass number A − 4. If Q_α is the Q - value of the decay, the kinetic energy of the emitted $\alpha-$ particle is $T_\alpha = Q_\alpha(1 - \frac{4}{A})$. Defend or Refute.

B10. The observed pattern (a Lissajous figure) on the screen of a cathode ray oscilloscope (CRO) becomes nearly stable when the ratio of two frequencies is a whole number however a perfect stability is achieved only when the sine wave generator is connected to a suitable series combination of capacitor and resistor. Defend or refute.

Part B_2 — 10x10 = 100

Solve all the 10 problems. Each carries 10 marks.

P1. (a) If $\frac{d\vec{A}}{dt} = \vec{\omega} \times \vec{A}$ and $\frac{d\vec{B}}{dt} = \vec{\omega} \times \vec{B}$, then show analytically that $\frac{d}{dt}\left(\vec{A} \times \vec{B}\right) = \vec{\omega} \times \left(\vec{A} \times \vec{B}\right)$

(b) Each second a rabbit moves half the distance from his nose to a carrot in a straight line. Does he ever get to the carrot? If so what time does he take? What is the limiting value of his average velocity? Show sketch of his position and velocity as function of time.

(c) The current in a resistance R decreases to half its value after each τ seconds. Obtain an expression for net amount of heat produced if a total charge Q flows through the resistance wire.

P2. A large uniform circular disc of radius R = 1.0 m and surface density $0.15\,kg/m^2$ is suspended at a peg through a hole at a distance $\ell = 0.8$ m from the centre. What is its time period of small oscillations? For what value of ℓ is the time period a minimum. Can you think of any other point on the disc collinear with the centre of suspension and the centre of gravity about which the time period is the same?

P3 Consider that a polytropic thermodynamic process with exponent η for a monoatomic ideal gas is the process P_η in which PV^η = constant

(a) What are the values of η for the isothermal, the adiabatic and the isobaric processes?

(b) Use the process equation and the equation of state to show that during the process P_η, the work done $PdV = \frac{R}{\eta - 1}dT$

(c) The specific heat of the given gas for process P_η is naturally defined as $C_{P_\eta} = Lim_{\delta T \to 0}\left(\frac{\delta Q}{\delta T}\right)_{PV^\eta = cons}$ Use this definition and the first law of thermodynamics to show that $C_{P_\eta} = \frac{R}{\gamma - 1} - \frac{R}{\eta - 1}$ where $\gamma = \frac{C_P}{C_V}$

P4. (a) Use Ampere's law to obtain an expression for magnetic field both outside and in-side a long straight current carrying cylindrical conductor of radius R. Thereby show that the magnetic energy stored per unit length within such a conductor is $U = \frac{\mu_0 i^2}{16\pi}$ J/m.

(b) Calculate the induced electro motive force produced across a metallic rod of length ℓ aligned along $\vec{\ell} = \hat{i} + 2\hat{j} + 3\hat{k}$ and moving under the influence of a magnetic field $\vec{B} = 3\hat{i} + 6\hat{j} + 9\hat{k}$ with a velocity $\vec{v} = 2\hat{i} + 4\hat{j} + 6\hat{k}$.

P5. The probability of occupancy of an energy level of energy E by electrons (each of mass m) in a Fermi gas at absolute Temperature T is given by the Fermi

distribution function $f(E)=\frac{1}{1+e^{\beta(E-E_F)}}$ where $\beta=\frac{1}{k_BT}$ k_B being the Boltzmann constant and ε_F is the Fermi Energy of the system.
At T= 0 K, the Fermi function turns out to

$$f(E)=\begin{cases}1 & for\ 0<E<E_F\\ 0 & for\quad E>E_F\end{cases}$$

If N electrons (fermions) are contained in a cube of volume V calculate

(a) the Fermi Energy ε_F.
(b) the pressure P exerted by the gas on the walls of the container

P6. (a) Obtain the minimum thickness of a calcite plate which would convert the plane polarised light of wavelength λ = 589 nm into circularly polarised light. Given that the principal refractive indices of calcite are μ_o=1.658 and μ_e=1.486 for the said wave length of light. What conditions need to be satisfied for such a conversion.

(b) A proton and a deuteron (a particle with same charge as that of proton but twice the mass) attempt to penetrate a one dimensional rectangular potential barrier height V_0=10 MeV and of thickness=10^{-14}m. Each particle has energy of 3 MeV. Evaluate the probability of success for both the particles.

P7. (a) A grounded conducting sphere of radius R is placed with its centre at the origin. A point charge +Q initially kept at (d,0,0) starts moving towards the sphere in the radial direction with velocity v. Determine the current in the cable that connects the sphere to the ground in terms of the velocity (v) of the charge and the instantaneous distance of the charge from the centre of the sphere.

(b) Consider an air pistol which is in the shape of a cylinder of initial volume 1 cm^3 at 250 kPa and 27^0 C. The bullet acts as a movable piston which is initially held by a trigger. When the trigger is pulled, the air in the cylinder expands adiabatically to a pressure of 100 kPa at the instant the bullet exits the muzzle of the pistol. If the mass of the bullet is 25 gm, determine the muzzle velocity of the bullet.

P8. (a) The kinetic energy of a relativistic particle of rest mass m_0 is twice its rest energy. What is the magnitude of the linear momentum of the particle?

(b) A metallic rod (negligible resistance) can slide frictionlessly on two parallel metallic rails separated by a distance ℓ in the presence of a perpendicular magnetic field (B). The ends of the rails are joined through a source of emf E and an inductance L in series. Obtain a differential equation for the velocity of the rod and show that the velocity varies simple harmonically about a mean value with a time period T. Obtain expressions for velocity and T.

P9. The deuterium-tritium fusion reaction
${}_1H^2 + {}_1H^3 = {}_2He^4 + {}_0n^1 + Q$ called D -T reaction may be the basic reaction for future nuclear reactors:

(a) Calculate the energy Q released in the reaction. Given that: The masses of
${}_1H^2$ atom = 2.014102 u, ${}_1H^3$ atom = 3.016050 u and
${}_2He^4$ atom = 4.002603 u, ${}_0n^1$ = 1.008665 u.

(b) Considering the radius of each of the ${}_1H^2$ and the ${}_1H^3$ nuclei to be 1.5 x 10^{-15} m, estimate the kinetic energy needed to overcome the electrostatic repulsion between them. To what temperature must the gases be heated to initiate the reaction. Use Boltzmann constant k_B = 1.38 X 10^{-23} J/K

P10. The voltage regulator circuit shown has a zener diode rated at 16 V, 200 mW. It is required that the circuit should dissipate 160 mW power across the fixed load resistor R_L. Find the range of the input voltage V_i suitable for the stable operation.