INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2015

Day and Date of Examination : Sunday, 25th January 2015

Time : 10 AM to 1 PM

Instructions to Candidates

1. In addition to this question paper, you are given **answer sheet for part A** and **answer paper for part B**.
2. On the answer 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 mark a cross (╳) 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.
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 likely 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

25×6=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. Poisson's equation for a potential function (V) can be written as

(a) $\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=\frac{\rho}{\varepsilon_0}$

(b) $\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right)+\frac{L^2 V}{r^2\hbar^2}=\frac{\rho}{\varepsilon_0}$

(c) $\nabla V=\frac{\rho}{\varepsilon_0}$

(d) $\nabla^2 V=\frac{\rho}{\varepsilon_0}$ where ρ and L are respectively the charge density and angular momentum operator. such that

$$L^2=\hbar^2\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right)+\frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\phi^2}\right]$$

2. The rotational kinetic energy of a molecule of diatomic gas is

(a) $E=\left(n+\frac{1}{2}\right)\hbar\omega$

(b) $E=\frac{J(J+1)\hbar^2}{2I}$

(c) $E=\frac{1}{2}Kx^2$

(d) $E=\frac{1}{2}I\omega^2$

3. A substance in superconducting state is
(a) perfect Ferromagnet
(b) perfect Paramagnet
(c) perfect Diamagnet
(d) perfect Dielectric.

4. Statement "The physical and chemical properties and hence the position of an element in the periodic table are decided by its atomic number rather than the atomic weight" is embedded in

(a) Duane Hunt Law
(b) Moseley law
(c) Laue's experimental law
(d) Bragg's law

5. Fine structure of Hydrogen α-line is explained by
(a) Rutherford atom model
(b) Bohr atom model
(c) Sommerfeld elliptical model with relativistic correction and spin of electron
(d) Spin orbit interaction combined with relativistic correction

6. It is known that one gram of water freezes as 1.091 cc of ice. The pressure at which water freezes at minus one degree celsius (-1°C) instead of 0°C is

(a) ≈136 cm of Hg
(b) ≈136 m of Hg
(c) ≈136 atm
(d) ≈1 atm

7. An electron moving with speed $\frac{c}{\sqrt{2}}$ in free space has
   (a) momentum $= m_0 c$
   (b) deBroglie wavelength = Compton wavelength
   (c) energy = twice its rest mass energy
   (d) kinetic energy $= m_0 c^2$

8. The quenching agent most often used in a Geiger Muller counter is
   (a) Hydrogen gas
   (b) Nitrogen gas
   (c) Oxygen gas
   (d) Chlorine gas

9. The particle decay $\Lambda^0 \rightarrow P^+ + \pi^-$ must be a weak interaction because
   (a) it does not conserve strangeness
   (b) no neutrino is produced in the decay
   (c) the π^- is a lepton
   (d) it does not conserve angular momentum

10. Whenever a dielectric substance is subjected to an external electric field **E**, it gets polarised temperature - dependent polarisation / phenomenon is / are
   (a) ionic polarisation
   (b) electronic polarisation
   (c) orientational polarisation
   (d) deformational polarisation

11. Which of the following is/are correct?
   (a) A ferromagnetic substance behaves as paramagnetic substance above a characteristic temperature known as Curie temperature (T_C)
   (b) An anti-ferromagnetic substance behaves as paramagnetic above a characteristic temperature known as Neel temperature (T_N)
   (c) A ferrimagnetic substance behaves as paramagnetic substance below a characteristic temperature known as Debye temperature (T_D)
   (d) Certain conducting substances behave as perfect diamagnet below a characteristic temperature known as Critical temperature (T_C).

12. A circular lamina of mass M and radius R with a non-uniform surface density

$$\rho(r) = \rho_0\left(1 - \frac{r}{R}\right) \text{ for } 0 \leq r \leq R$$

   is rotating about its own axis perpendicular to its plane and through its centre with an angular velocity ω. Its
   (a) Moment of inertia is $= \frac{1}{2}MR^2$
   (b) Moment of inertia is $= \frac{3}{10}MR^2$
   (c) Angular momentum is $= \frac{1}{2}MR^2\omega$
   (d) None of these is correct.

13. In a laboratory measurement the energy of a particle is measured to be $E = 0.08eV$. It may be
   (a) A photon of wavelength 1 $A°$
   (b) An electron of de Broglie wavelength 1 $A°$
   (c) A proton of de Broglie wavelength 1 $A°$
   (d) A neutron of de Broglie wavelength 1 $A°$

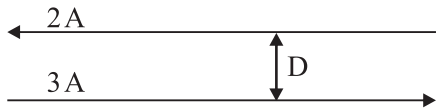
14. The motion of a particle of mass m in a resistive medium [resistive force (F) being proportional to velocity ($\propto -v$)] under the simultaneous influence of a linear restoring force $= -Kx$ and an external periodic force $= F_0 \sin \omega t$ is described by the differential equation

$$m\frac{d^2x}{dt^2} + r\frac{dx}{dt} + Kx = F_0 \sin\omega t$$

   Such a motion is
   (a) Simple harmonic motion
   (b) Damped harmonic motion
   (c) Maintained oscillations
   (d) Forced Oscillations

15. The molar specific heat of a classical ideal gas in a polytropic process ($PV^n = const$) is expressed as
   (a) $C = \frac{R}{n-1}$
   (b) $C = \frac{R}{\gamma - 1}$
   (c) $C = \frac{R}{\gamma - 1} + \frac{R}{n-1}$
   (d) $C = \frac{R}{\gamma - 1} - \frac{R}{n-1}$

16. Two long parallel and horizontal wires, each of radius r, carrying current 2A & 3A, respectively, are arranged in a vertical plane, one above the other. The lower wire is clamped fix while the upper one is free to move up & down in vertical plane and maintains an equilibrium separation of D. [The length of each wire L>>D]



The upper wire is pressed slightly and realeased so as to execute simple harmonic motion in vertical plane. The observed time period of such a motion is

(a) $T = 2\pi\sqrt{\frac{L}{g}}$

(b) $T = 2\pi\sqrt{\frac{D}{g}}$

(c) $T = 2\pi\sqrt{\frac{\mu_0}{2\pi}\frac{2\times 3L}{g}}$

(d) $T = 2\pi\sqrt{\frac{\mu_0}{2\pi}\frac{2\times 3D}{g}}$

17. A silicon diode dissipates 3.2 watt at a current of 2A.
(a) Forward voltage drop is 6.4 volt
(b) Forward voltage drop is 1.6 volt
(c) The bulk resistance R_b is 0.45 Ω
(d) The bulk resistance R_b is 0.80 Ω

18. A non-conducting sphere of radius R is charged with volume charge density $\rho = \rho_0\left(1 - \frac{r}{R}\right)$ where ρ_0 is constant and r denotes any position with respect to centre of the sphere. Assuming ε to be the permittivity of the medium of the sphere.

(a) The magnitude of the electric field **E** as a function of distance r outside the ball is given by $E = \frac{\rho_0 R^3}{12\varepsilon_0 r^2}$ *for* $r \geq R$

(b) The magnitude of electric field **E** as a function of distance r inside the ball is given by $E = \frac{\rho_0 r}{3\varepsilon}\left(1 - \frac{r^2}{4R}\right)$ *for* $r \leq R$

(c) The maximum value of electric field

$$E_{max} = \frac{\rho_0 R}{9\varepsilon} \; at \; r = \frac{2}{3}R$$

(d) The total energy stored in this charged non-conducting sphere is $U = 0.021\frac{\rho_0^2 R^5}{\varepsilon}$

19. Suitable dichroic material used as a Polaroid film may be
(a) Either of tourmaline, quartz or calcite
(b) Substance with sugar content such as glucose or fructose.
(c) Idosulphate of quinine (Herapathite)
(d) Stretched polyvinyl alcohol films impregnated with iodine.

20. In EM theory, the Physical quantity $\vec{\mathbf{D}}\times\vec{\mathbf{B}} = \varepsilon_0 \vec{\mathbf{E}} \times \vec{\mathbf{B}}$ is expressed in unit of

(a) $\frac{\text{Work}}{\text{sec}\times\text{m}^2}$

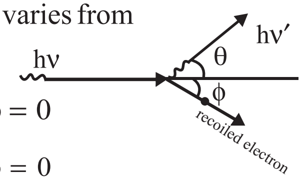
(b) $\frac{\text{Momentum}}{\text{Volume}}$

(c) $\frac{\text{Angular impulse}}{\text{Volume}}$

(d) $\frac{\text{Impulse}}{\text{m}^3}$

21. The average distance travelled by an excess carrier between the time of its generation and recombination in a semiconductor is known as
(a) coherence length
(b) diffusion length
(c) depletion width
(d) band width

22. In an event of Compton scattering, of incident monochromatic X-ray beam when the angle of scattering varies from $\theta = 0$ to $\theta = \pi$, the angle ϕ at which the target electron recoils varies from



(a) $\phi = \frac{\pi}{4}$ *to* $\phi = 0$

(b) $\phi = \frac{\pi}{3}$ *to* $\phi = 0$

(c) $\phi = \frac{\pi}{2}$ *to* $\phi = 0$

(d) $\phi = \pi$ *to* $\phi = 0$

23. Two electrons are revolving in opposite sense in s orbital of a hydrogen like atom. The magnitude of magnetic dipole moment induced when the same is subjected to an external magnetic field $B \approx 1$ tesla perpendicular to the plane of circulation is/are

(a) $\Delta\mu = \frac{\hbar}{2\pi}$

(b) $\Delta\mu = \frac{e^2 R^2 B}{4m}$

(c) $\Delta\mu = \frac{e^2 R B}{4\pi m}$

(d) $\Delta\mu = \frac{e^2 R B}{4m}$

24. The torque required for twisting of a long cylindrical solid shaft is

(a) independent of the nature of its material

(b) propotional to the squae of its area of cross section.

(c) Inversely proportional to its length.

(d) greater than that for a hollow shaft of same mass, material and length.

25. Which of the following eigen states $\Psi_{nlm}(r\,\theta\phi)$ of a quantum system such as hydrogen atom have even parity

(a) $\Psi_{100}(r\theta\phi) = \frac{1}{\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{\frac{3}{2}} e^{-\frac{Z}{a_0}r}$

(b) $\Psi_{200}(r\theta\phi) = \frac{1}{2\sqrt{2\pi}}\left(\frac{Z}{a_0}\right)^{\frac{3}{2}}\left(1-\frac{Z}{2a_0}r\right)e^{-\frac{Z}{2a_0}r}$

(c) $\Psi_{211}(r\theta\phi) = -\frac{1}{8\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{\frac{5}{2}} r\, e^{-\frac{Z}{2a_0}r}\sin\theta\, e^{i\phi}$

(d) $\Psi_{300}(r\theta\phi) = \frac{1}{3\sqrt{3\pi}}\left(\frac{Z}{a_0}\right)^{\frac{3}{2}}\left(1-\frac{2Z}{3a_0}r+\frac{2}{3}\left(\frac{Z}{3a_0}r\right)^2\right)e^{-\frac{Z}{3a_0}r}$

PART B-1 (10 x 5 = 50)

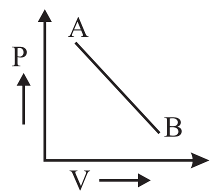
Answer all the following in brief (not more than 10 lines) with appropriate reasoning

B_1 Infinitesimal rotations are vectors where as finite rotations are not. Explain.

B_2 Stefan Boltzmann law can be derived from Planck's radiation formula. Show.

B_3 In a hypothetical world, if Planck constant (h) were much smaller than its present value, the results of quantum mechanics would then have been more conspicuous (noticeable) than they are! Defend or refute.

B_4 In a thermodynamical process, the variation of pressure against volume of a classical ideal diatomic gas ($\gamma = 1.4$) is a straight line AB with negative slope. In going along AB, the internal energy of the ideal gas, first increases and then decreases. Explain why?



B$_5$ A photon of energy $E \geq 1.02\ MeV$ in free space (vacuum) cannot produce an electron-positron pair. Explain why?

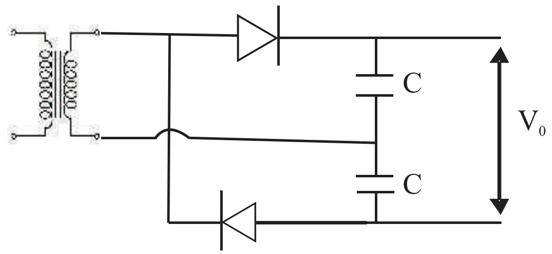
B$_6$ More compact is an electric charge distribution more difficult is to assemble it. Justify

B$_7$ In simple co-ordinate space $p_{op} = -i\hbar \frac{\partial}{\partial x}$ represents the momentum operator. What does $i\hbar \frac{\partial}{\partial p}$ stand for? Explain.

B$_8$ Mixing of any two samples of a classical ideal gas essentially causes an increase in entropy. Justify

B$_9$ The reciprocal lattice for a bcc crystal structure is an fcc lattice. Show

B$_{10}$ The circuit below is a voltage multiplier. Identify its nature and explain its working.



PART B-II (10 x 10 = 100)

Solve all the ten problems. Each carries ten marks

P$_1$ A ball of mass m = 100 g moving with a non-relativistic speed u makes a head on collision with an identical ball at rest. Estimate

(a) the speed of two balls after the collision, if the collision is elastic

(b) the coefficient of restitution, if the kinetic energy after the collision is three-fourth of its original value.

(c) the maximum and the minimum values of u if the total energy after collision is found just to be 0.2 joule.

P$_2$ Two spherical masses A and B of same radius R and density ρ and 4ρ, respectively, are located at a distance D = 6R apart in a gravity free space. What should be the minimum velocity of projection of a small ball of mass m = 1kg from the surface of A so as directly to reach B ? use $\rho R^2 = 2.1 \times 10^{10}$ Kg/m

P$_3$ (a) Mu mesons (μ^-, μ^+) are leptons 207 times heavier than an electron. A proton often captures a negative mu meson (μ^-) to form a "mesic atom" Find the radius of the first Bohr - orbit of such a mesonic atom. This provided a strong basis for estimation of nuclear radius in early days.

(b) At what temperature the molecular kinetic energy in gaseous hydrogen equals the binding energy of hydrogen atom?

P$_4$ A plane transmission diffraction grating with 6000 lines per cm is used to study diffraction of polychromatic light. Calculate the angular dispersion in the second order spectrum around the wave length 5890 $A°$. What will be the linear dispersion if the spectrum is focused by a spectrometer using a lens of focal length 25cm? Also estimate the linear separation between 5890$A°$ and 5896$A°$ in the second order as observed by this arrangement and the width of the ruled space.

P_5 A microscopic particle of rest mass m_{01} moving with speed u_1 collides with another particle of rest mass m_{02} initially at rest. After the collision the two particles coalesce together and move in the same direction with velocity V. Show that the rest mass (M_o) of this composite particle after collision is given by $M_0^2 = m_{01}^2 + m_{02}^2 + \frac{2m_{01}m_{02}}{\sqrt{1-\frac{u_1^2}{c^2}}}$

Obtain an expression for final velocity V.

P_6 How does the internal energy of a real gas differ from that of an ideal gas? Explain the meaning of two types of specific heat of a gas. Show that the two are related as

(a) $C_P - C_V = R$ for a classical ideal gas and

(b) $C_P - C_V = R\left[1 - \frac{2a}{VRT}\right]$ for a Vander Waal gas.

Here V is the specific volume. Maxwell thermodynamical relations may be used.

P_7. Obtain the eigen values and discrete eigen states of a particle confined in a one dimensional infinite potential well of width 'a' centered at x = 0. Locate the positions of maximum probability of finding the particle in first three eigen states. Find expectation value $<x>$ and $<x^2>$ in the n[th] state Ψ_n. Hence find the uncertainty $\Delta x = \sqrt{<x^2> - <x>^2}$ in the position of the particle in its n[th] state.

P_8 In a laboratory measurement, Zeeman splitting of the sodium yellow spectral line $\lambda = 5890 A°$ is observed to be $\Delta\lambda = 0.161 A°$. when subjected to an external magnetic field $B = 1.0$ T. Using the observed values, estimate the charge to mass ratio $\left(\frac{e}{m}\right)$ of an electron.

What would be the base thickness of a prism capable to just resolve this doublet if the dispersion for the material of the prism be $\left(\frac{d\mu}{d\lambda}\right) = 8888\ cm^{-1}$?

P_9 How is magnetic induction (**B**) expressed in terms of vector potential (**A**)? Obtain an expression for magnetic vector potential due to a long straight current carrying condutor. Show analytically that the magnetic vector potential (**A**) for two long parallel wires carrying equal and opposite current (I) is expressed as

$\mathbf{A} = \frac{\mu_0 I}{4\pi} \ln\left(\frac{R_2}{R_1}\right)\hat{\eta}$ where R_1 & R_2 are respectively, the $\perp$ distances of the point of observation from the two wires and $\hat{\eta}$ is a unit vector parallel to one of the the currents.

P_{10}. For the emitter follower circuit, determine the values of r_e, Z_i, Z_o, and A_V.