INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2011-12

Day and Date of Examination : Sunday, 22nd January 2012

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.

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

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.

Q1. A three dimensional length element $d\mathbf{l} = dx\mathbf{i} + dy\mathbf{j} + dz\mathbf{k}$ in cartesian coordinates (x,y,z) may be expressed in spherical polar coordinates (r,θ,ϕ) as

(a) $d\mathbf{l} = dr\,\mathbf{e}_r + d\theta\,\mathbf{e}_\theta + d\phi\,\mathbf{e}_\phi$

(b) $d\mathbf{l} = dr\,\mathbf{e}_r + rd\theta\,\mathbf{e}_\theta + rd\phi\,\mathbf{e}_\phi$

(c) $d\mathbf{l} = dr\,\mathbf{e}_r + rd\theta\,\mathbf{e}_\theta + r\sin\theta d\phi\,\mathbf{e}_\phi$

(d) $d\mathbf{l} = dr\,\mathbf{e}_r + rd\theta\,\mathbf{e}_\theta + r\sin d\phi\,\mathbf{e}_\phi$

Here $\mathbf{e}_r$, $\mathbf{e}_\theta$ and $\mathbf{e}_\phi$ are respective unit vectors.

Q2. A semicircular arc and a quadrant of a circle each of mass M and radius R are rotated about an axis perpendicular to their planes and passing through centre of the circle. If their moments of inertia be I_1 and I_2 then

(a) $I_1 = I_2 = MR^2$

(b) $I_1 = 2MR^2$, $I_2 = MR^2$

(c) $I_1 = MR^2$, $I_2 = 2MR^2$

(d) $I_1 = I_2 = 2MR^2$

Q3. The magnetic field ($d\vec{B}$) produced by a current element is empirically given by Biot Savart law which states that

(a) $d\vec{B} = \frac{\mu_0}{4\pi} \frac{idl\sin\theta}{r^3} \vec{r}$

(b) $d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\vec{dl} \times \vec{r}}{r^3}$

(c) $d\vec{B} = \frac{\mu_0}{4\pi} \frac{\vec{J} \times \vec{r}}{r^3} dV$

(d) $d\vec{B} = \frac{\mu_0}{4\pi} \frac{\vec{J} \times \vec{r}}{r^5} dV$

Q4. The coherence length for the sodium light of wave length 589 nm is 0.02945 m. The coherence time would be

(a) $\approx 20\,\mu s$

(b) ≈ 20 ms

(c) ≈ 0.1 ps

(d) ≈ 0.1 ns

Q5. A particle moves in such a way that its distance (R) from a fixed center is constant and its speed is always proportional to the distance (S) travelled by it. The angle between its acceleration and velocity vector as a function of the distance is

(a) $\tan^{-1}(S/R)$

(b) $\sin^{-1}(S/R)$

(c) $\cos^{-1}(S/R)$

(d) None of these

Q6. The period of oscillation of a linear harmonic oscillator is 1 s. Its zero point energy is

(a) 2h

(b) h

(c) h/2

(d) Data is insufficient

Q7. The principal series of hydrogen atom is observed during the transition of electron from

(a) s to p state

(b) p to s state

(c) d to p state

(d) p to d state

Q8. The number of microstates accessible to a statistical system in the energy range E to E+dE is proportional to

(a) E
(b) $E^{½}$
(c) $E^{-½}$
(d) E^{-1}

Q9. The induced emf across a metallic rod, of length (l), rotating with angular speed (ω) around a fixed axis (|| B) with its length always along the radius and the nearest end being at a distance 2l from rotation axis is

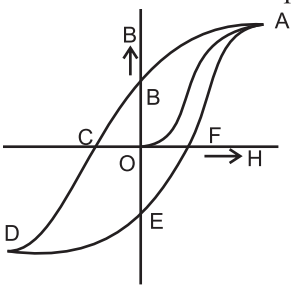
(a) $2B\omega l^2/2$
(b) $3B\omega l^2/2$
(c) $4B\omega l^2/2$
(d) $5B\omega l^2/2$

Q10. A capacitor loses a certain fraction of its charge in 30 s because of humidity in the air giving rise to leakage between its terminals (plates). When a 4 MΩ resistance is connected between its terminals, the same fraction of charge is found to be lost in 10 s. The leakage resistance is

(a) 2 MΩ
(b) 4 MΩ
(c) 8 MΩ
(d) 16 MΩ

Q11. In the interior of a permanent magnet, the magnetizing field H is found to be directed opposite to the magnetic induction B. On a B-H curve, the situation refers to the part

(a) OA
(b) AB
(c) BC
(d) CD



Q12. The fact, that the boiling and melting points of a liquid change with the pressure, is explained by the equation /equations

(a) $\frac{dP}{dT} = \frac{L}{T(V_2 - V_1)}$

(b) $\left(\frac{dT}{dP}\right)_H = -\frac{1}{C_p}\left[\frac{2a}{Rb} - T\right]$

(c) $C_2 - C_1 = \frac{dL}{dT} - \frac{L}{T}$

(d) $\left(\frac{\partial P}{\partial T}\right)_V = -\left(\frac{\partial S}{\partial V}\right)_T$

Q13. Tunnel effect is purely a quantum mechanical concept absolutely inconceivable in classical Physics. Which of the following phenomena, observed in nature, is/are in support of quantum mechanical tunneling?

(a) Alpha decay of an atomic nucleus
(b) Ammonia inversion
(c) Current in a tunnel Diode
(d) Field emission of electrons from a metal

Q14 Which of the following statements is/are correct regarding various nuclear interactions?

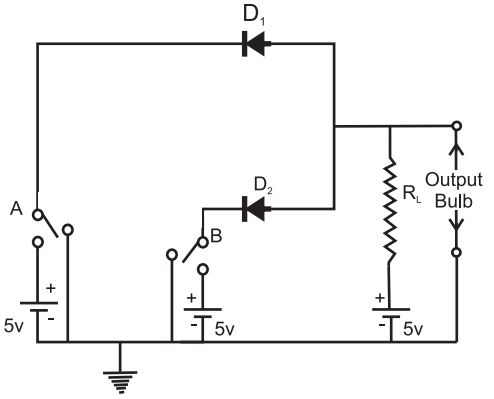
(a) Iso-spin is conserved in strong interaction
(b) Iso-spin is not conserved in week interaction
(c) Iso-spin is not conserved in electro magnetic interaction
(d) Z-component of Iso-spin is conserved in strong and electromagnetic interactions.

Q15 Ursa Major (Saptarishi) seen in the sky is

(a) An Asteroid
(b) A Binary Star
(c) A Comet
(d) A Constellation

Q16. The phenomenon of complete exclusion of magnetic flux (complete diamagnetism) from a substance in superconducting state is known as
(a) Cooper effect
(b) Meissner effect
(c) Josephson effect
(d) Magneto-encephalography

Q17. The circuit shown below is the realization of a
(a) OR gate
(b) NOT gate
(c) AND gate
(d) XOR gate



Q18. A microscopic particle of mass m, moving along x-axis between the limits $-a \le x \le a$ with zero potential energy, is described by a wave function $\psi = A\sin\frac{n\pi x}{2a}$. If the potential in the region $-a > x > a$ is infinite $(V = \infty)$ then

(a) The normalization constant $A = \sqrt{\frac{1}{a}}$

(b) The normalization constant $A = \sqrt{\frac{2}{a}}$

(c) The energy eigen values $E_n = \frac{n^2\pi^2h^2}{8ma^2}$

(d) The energy eigen values $E_n = \frac{n^2\pi^2h^2}{2ma^2}$

Q19. With the discovery of proton in 1919, a carbon nucleus ${}_6C^{12}$ was supposed to have 12 protons and 6 electrons. This idea of the presence of electrons in the nucleus was later discarded because
(a) It was against neutrality of atom.
(b) It could not account for the mass and energy of nucleus
(c) It could not account for the angular momentum and parity of nucleus
(d) It could not account for the magnetic dipole moment of nucleus

Q20. Consider the following four waves with E_x & E_y as the two components of the corresponding electric vector
P: $E_x = E_0\sin(Kz-\omega t+\pi/3)$;
$E_y = E_0\sin(Kz-\omega t-\pi/6)$
Q: $E_x = E_0\cos(\omega t+Kz)$;
$E_y = E_0\cos(\omega t+Kz+\pi/2)$
R: $E_x = E_0\cos(Kz-\omega t+\pi/4)$;
$E_y = E_0/\sqrt{2}\sin(Kz-\omega t)$
S: $E_x = E_0\cos(\omega t-Kz)$;
$E_y = E_0\sqrt{2}\cos(\omega t-Kz)$
(a) P: is LP and Q: is CP
(b) Q; is CP and R: is EP
(c) S: is LP and P: is CP
(d) P: is CP and Q: is CP
Where LP means linearly polarized, CP means circularly polarized and EP is elliptically polarized

Q21. During severe winter, in the low temperature zones on the earth, the superficial (upper) parts of lakes are frozen, leaving water below a critical thickness of ice. The freezing near the bottom is prevented because
(a) The conductivity of ice is low.
(b) The water has large specific heat.
(c) The latent heat of fusion for water is large
(d) The earth's crest below the lake has high temperature

Q22. In a p-n junction, a free hole diffuses from p-region to n-region. This means that a
(a) Covalent bond is broken on the n-side and the electron freed from the bond jumps to the conduction band.
(b) Conduction electron on the p-side jumps to the broken bond to complete it.
(c) Covalent bond is broken on n-side and the electron freed from the bond jumps to the broken bond on the p side to complete it
(d) Covalent bond is broken on p-side and the electron freed from the bond jumps to the broken bond on the n-side to complete it.

Q23. The binding energy per nucleon is observed to be almost the same for many nuclides. This indicates that the strong nuclear forces are
(a) Attractive
(b) Short range
(c) Charge independent
(d) Saturated

Q24. Though there is a finite probability of finding a particle any where in a one dimensional potential well yet, in its lowest energy state, it has the maximum chance to be found
(a) Very close to the walls
(b) Exactly at the centre between the walls
(c) Midway between the walls and the centre
(d) Equal chances to be any where in the well

Q25. In a solid state Ruby LASER
(a) For better lasing 0.05% Al^{+++} ions in Al_2O_3 are replaced by Cr^{+++} ions.
(b) Xenon flash lamp is used for optical pumping for population inversion.
(c) The output appears in pulses which lasts for a duration of 10^{-6} s.
(d) It emits the doublet $\lambda_1 = 694.3$ nm and $\lambda_2 = 692.9$ nm with the instantaneous output power pulse being ≈Mega watt.

PART B-1 (10 x 5 = 50)

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

B_1 What makes it wrong, if Coulomb's Law for the force between two charges is expressed as $F=\frac{K}{r^n}$ with $n\neq 2$? Explain.

B_2 A physical system subjected to a driving force experiences mechanical impedance (Z_m). How do you express the mechanical impedance (Analogous to an A C circuit) experienced by a system (body) executing forced oscillations? Explain its physical significance.

B_3 The elastic behavior of a bent beam is described in terms of its Young's modulus (Y) and not in terms of modulus of rigidity (η) even though the beam has been deshaped. Explain.

B_4 The temperature of inversion (T_i), in porus plug experiment, for a real gas obeying Vander Waal equation is twice its Boyle temperature (T_B). Support or refute.

B_5 An astronaut takes a trip to Sirius located at a distance of 8 light year from the earth. The astronaut measures the time of one way journey equal to 6 year when the space ship moves at a constant speed v = 0.8c. How can the 8 light year distance be reconciled with a 6 year time when the speed is not even c?

B_6 The quantum mechanical wave function $\psi = \psi_0 e^{-i(kx-\omega t)}$ represents a stationary state solution of Schrodinger equation of a free particle. Justify

B_7 Usually the specific heat (C_{vapour}) of saturated water vapours is given by

$$C_{vapour} = C_{water} + \frac{dL}{dT} - \frac{L}{T}$$

with C_{water}=1.01 cal/g°K and

L=800–0.705T cal/g. This yields a negative value of specific heat of saturated vapours. Justify and explain the meaning of the negative value of specific heat of saturated water vapours.

B_8 Silicon chips are preferred over those of germanium for manufacturing various electronic components. Explain why?

B_9. In Young's double slit experiment a screen with a single punch pin hole is symmetrically placed before the two pin holes. Explain why? What will be wrong if source of monochromatic light is directly placed before the two pin holes?

B_{10} How would you distinguish whether a given transparent plate is quarter wave plate (QWP), half wave plate (HWP) or an ordinary plate. You can use only two polarizer and a source of light.

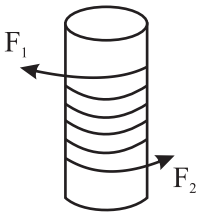
PART B-II (10 x 10 = 100)

Solve all the following problems. Each carries ten marks.

P1 The amplitude of an under damped harmonic oscillator of time period T=1.15 s, decreases to 1/10 of its initial value (the first throw) after 100 oscillations. Calculate the damping constant (λ) and the relaxation time (τ). What would be the undamped amplitude of such an oscillator (in the absence of any damping) If the observed value of the first throw is a_1=2 cm?

P3 To moor a ship, a sailor often wraps a rope around a bollard (a cylindrical post). By pulling the rope at one end with a small force F_1, he can exert a much larger tension F_2 on the other end of the rope attached to the ship because of the friction between the rope and the bollard.

If the coefficient of friction between the rope and the bollard be μ = 0.4 and the sailor pulls with F_1 = 400 N, how many turns of the rope are needed round the bollard, if a force of $F_2 = 2.4 \times 10^6$ N is to be exerted on the ship?



P2(a) What is the wattage of a tungsten filament lamp if the operating temperature of the tungsten filament in the bulb is 3000 K, its emissivity is 0.35 and the surface area of the filament is 0.25 cm^2? Given that Stefan's constant $\sigma = 5.67 \times 10^{-8}$ watt/m^2K^4

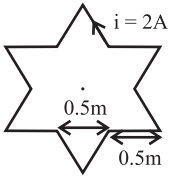
(b) Calculate the root mean square speed of hydrogen molecules at room temperature (27°C). Compare this value with the velocity of sound in hydrogen at the same temperature.

P4. Linearly polarized light is incident normally on a calcite crystal whose optic axis lies in the plane of incidence and is inclined at an angle ($\theta \neq 0, 90$) with the plane of incidence. Draw a diagram to show double refraction. Mark on it the two wave fronts for ordinary and extra-ordinary rays, the direction of propagation (**K** vector), the direction of Poynting Vector (**S**), the **D** and **E** vectors both for O-ray and E-ray respectively.

P5. What is Hall effect? Show analytically that the ratio of Hall electric field (E_H) developed across a given sample to the electric field (E) responsible for the current is independent of conductor dimensions and is expressed as $\frac{E_H}{E} = \frac{B}{ne\rho}$

Estimate Hall voltage across a silver ribbon b = 0.50 cm wide and t = 0.10 mm thick carrying a current of 5.0 A when placed in a perpendicular magnetic field B = 1.60 T acting along its thickness.

P6. To construct a star like network as shown, each of the six sides of a regular hexagon is stretched out to form equilateral triangle on the original side of length 0.5 m and a current of 2 A is passed through the closed circuit. Obtain an expression for magnetic induction (B) at the centre. Also estimate its magnetic dipole moment expressing its direction.



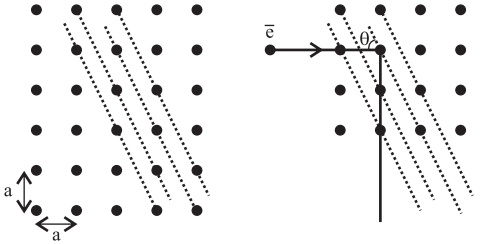
P7(a) Show that the effective force exerted by a large water reservoir against a dam of width W and height H is $F = \frac{\rho g W H^2}{2}$ and effective center of this force is at a height $h = \frac{H}{3}$ above the bed (bottom).

(b) Show that the relativistic form of Newton's second law of motion is $F = \frac{m}{\left(1 - \frac{v^2}{c^2}\right)} \frac{dv}{dt}$

and not $F = m\frac{dv}{dt}$ for a particle of mass m moving with velocity v comparable to c.

P8. One way to treat/cure the cancer of thyroids is to inject radio active iodine (I-131) in the body of a patient where iodine tends to accumulate in the thyroid glands and kills the cancer cells. Through a biological process the body excretes iodine exponentially with a half life of 7 days while the half life of radioactive iodine (I-131) is 8 days. How long will it take to reduce the level of radioactive iodine to 0.1 % of its initial doze in the patient as a cumulative effect of the two processes?

P9 Rock salt forms a cubic lattice with lattice constant of 5.63 A°. (a) What is the crystal spacing between the lattice planes marked as broken lines? (b) What should be the accelerating potential for an electron to get reflected off the planes indicated when electron beam is incident on it?



P10(a) In a piece of intrinsic germanium, there are $n_i = 6 \times 10^{19}$ electrons/m^3. Calculate the conductivity of this material if it has been doped with phosphorus to the extent that the number of free electrons/m^3 turns out to $n = 2 \times 10^{23}$. Given that the mobility of free electrons and holes are $\mu_e = 0.39 m^2/Vs$ & $\mu_h = 0.19\ m^2/Vs$ respectively.

(b) Calcuate the output parameters V_L, V_R, I_Z and P_Z of the given network where break down voltage is $V_Z = 10V$ and $P_{ZMax} = 30$ mW for the Zener diode.