INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2013-2014

Day and Date of Examination : Sunday, 19th January 2014

Time : 10 AM to 1 PM

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.

Q1. Which of the following vector operations make significance and is/are correct
(a) Curl of a curl is always zero
(b) Curl of a grad is always zero
(c) Div of a curl is always zero
(d) Grad of a div is always zero

Q2. The dragging force acting on a sky diver is proportional to its velocity. The variation of its velocity (v) as a function of time is described by
(a) $V=V_T\,[1-e^{-\frac{gt}{Km}}]$
(b) $V=V_T\,e^{-\frac{gt}{Km}}$
(c) $V=u+gt$
(d) $V=V_T\,e^{\frac{gt}{Km}}$
V_T being the terminal velocity & K is const.

Q3. A common observation while performing Poiseuille's experiment for measurement of viscosity of a liquid is that the volume verses pressure curve looses linearity for increasing difference in the liquid heights in two limbs. It may be due to the fact that
(a) Liquid flow becomes stream line
(b) Turbulence starts
(c) Speed of liquid flow exceeds critical value.
(d) The effect of gravity gains significance

Q4. Under Lorentz transformations
(a) Momentum is invariant
(b) $E^2 - p^2c^2$ is invariant
(c) Mass-energy is invariant
(d) $x^2+y^2+z^2-c^2t^2$ is invariant

Q5. Under normal conditions of pressure and temperature, the saturated water vapours exhibit a negative specific heat because
(a) Vapours cool on heating
(b) Temperature increases only when heat is abstracted
(c) Saturation is lost on heating
(d) Heat must be abstracted to maintain saturation at higher temperature

Q6. The voltage gain in a RC coupled single stage transistor amplifier
(a) Increases with frequency
(b) Remains constant over entire frequency range
(c) Remains constant in the intermediate frequency range
(d) Decreases with frequency only in the higher frequency range.

Q7. Any rigid body can acquire equilibrium if it is acted upon by
(a) A single force
(b) Two non-liner forces
(c) Three non-coplanar forces
(d) Any number of forces

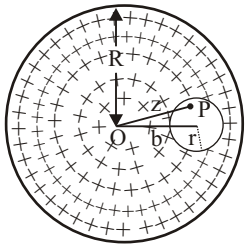
Q8. The electric field (E) produced at point P inside a spherical cavity of radius r in a uniformly charged non conducting sphere of radius R with uniform volume charge density ρ is

(a) $E = \frac{\rho R}{3\varepsilon_0}$

(b) $E = \frac{\rho r}{3\varepsilon_0}$

(c) $E = \frac{\rho b}{3\varepsilon_0}$

(d) $E = \frac{\rho(R-r)}{3\varepsilon_0}$



Q9. One parsec is

(a) The length of an arc traversed by earth to subtend an angle of 1″ at the centre of sun.

(b) The time light takes to travel from sun to earth.

(c) The time a light signal takes to travel once around the earth.

(d) Equal to 2.76 light year

Q10. The glancing angle through which an X-ray beam of wave length λ = 0.710 A° will be reflected strongly in second order from the face (110) of a cubic crystal of rock salt with a = 2.828 A°

(a) 14°32′

(b) 07.21°

(c) 20°48′

(d) 20.80°

Q11. More than one, linearly independent eigen functions of a quantum mechanical system are found to belong to the same energy eigen value E. Such an energy eigen value E is said to be

(a) Orthogonal

(b) Orthogonal and degenerate

(c) Degenerate

(d) Non-degenerate

Q12. The differential equation

$m\frac{d^2x}{dt^2} + r\frac{dx}{dt} + Kx = 0$ describes the motion of a particle of mass m in a resistive medium. Such a motion is

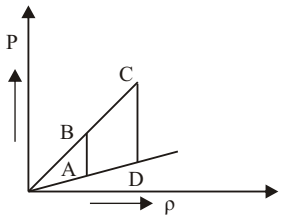
(a) Simple harmonic motion

(b) Damped harmonic motion

(c) May be over damped motion

(d) Forced Oscillations

Q13. Pressure verses density graph of a certain mass of an ideal gas is shown below



(a) The non-zero work done by the gas during the process AB is positive

(b) The non-zero work done by the gas during the process AB is negative

(c) The internal energy of the gas increases along BC

(d) None

Q14. The baryon number is zero for

(a) Proton

(b) μ meson

(c) π meson

(d) Lepton

Q15. When a magnetic material is subjected to an external magnetising field, its ability to get magnetized is described in terms of

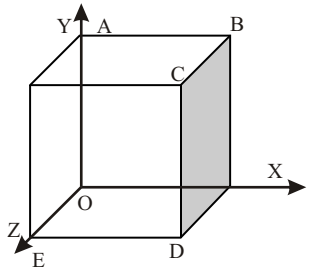
(a) Magnetic permeability

(b) Magnetic susceptibility

(c) Magnetic viscosity

(d) Magnetic resonance

Q16. A particle moves under the influence of the force F = yi + zj + xk N along the edges of a unit cube (edge length = 1m) on the path OA-AB-BC-CD-DE-EO. Then the

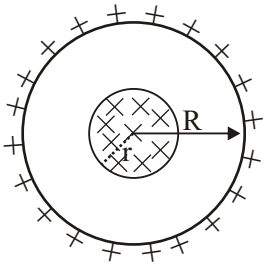


(a) total work done is zero
(b) total work done is = 1 joule
(c) total work done is = 3 joule
(d) force F is conservative.

Q17. Superposition theorem can be applied to a circuit having
(a) Non-linear elements
(b) Passive elements
(c) Linear elements
(d) Resistive elements

Q18. A ring of radius R, made up of non-conducting material is given a charge q uniformly distributed all over its circumference. In the circular region of radius r at the centre of the ring, a magnetic field B, perpendicular to the plane of the ring, varies at a constant rate $\frac{dB}{dt} = \beta$
Torque acting on the charged ring is

(a) $\frac{1}{2} qr^2 \beta$
(b) $\frac{1}{2} qR^2 \beta$
(c) $\frac{1}{2} \frac{qr^4 \beta}{R^2}$
(d) Zero



Q19. Crystal planes are described by a set of specific numbers known as Miller Indices. The intercepts cut by a plane on the respective axis are 2, 3 & 5. The Miller indices of such a plane are
(a) 2,3,5
(b) 15,10, 6
(c) 6,9,15
(d) None

Q20. When a slab of dielectric material is placed in an external electric field .
(a) All its atoms get polarised.
(b) Polarisation charge appears on its surfaces perpendicular the field direction.
(c) The electric field gets modified inside the dielectric material.
(d) Gauss's law can still be applied to this situation for the polarisation charge.

Q21.According to vector atom model, the angular momentum (l) of an electron is conserved and quantized. Quantum mechanics therefore predicts that
(a) Its magnitude is $l\hbar$
(b) Its magnitude is $\sqrt{l(l+1)}\,\hbar$
(c) Its orientation with magnetic field is $\cos^{-1}\left(\frac{m}{\sqrt{l(l+1)}}\right)$
(d) Its orientation with magnetic field is $\cos^{-1}\left(\frac{l}{\sqrt{l(l+1)}}\right)$

Q22. In context of the fabrication of an IC 'metallization' means
(a) Connecting metallic wires
(b) Forming interconnecting conduction pattern and bonding pads
(c) Depositing SiO_2 layer
(d) Covering with a metallic cap.

Q23. Nodal slide experiment in an undergraduate laboratory is based on the principle that

(a) The separation between two nodal points of a coaxial system equals that between two principal points.

(b) The image formed in focal plane does not shift laterally when a coaxial system is rotated about a vertical axis passing through second nodal point.

(c) Nodal points coincide with the principal points when the media on the two sides are same.

(d) Focal length is the separation between the principal point and the focal point.

Q24. In a process of modulation, high frequency radio waves are used as carrier waves because such waves

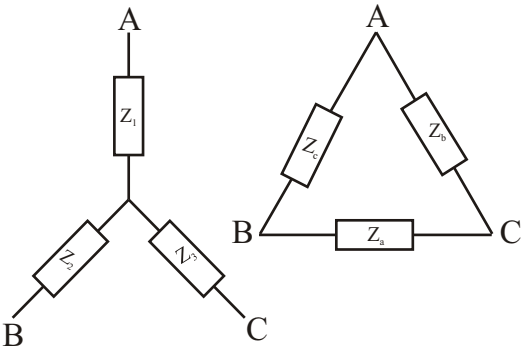
(a) Are undamped

(b) Contain more power

(c) Travel faster

(d) Require small transmitting antenna

25. In a three terminal network of impedances Z_1 Z_2 & Z_3 connected as a star, the impedances Z_a, Z_b & Z_c in an equivalent delta are related as



(a) $Z_3 = \dfrac{Z_a Z_b}{Z_a + Z_b + Z_c}$

(b) $Z_1 = \dfrac{Z_b Z_c}{Z_a + Z_b + Z_c}$

(c) $Z_1 = \dfrac{Z_c Z_a}{Z_a + Z_b + Z_c}$

(d) $Z_c = \dfrac{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}{Z_3}$

PART B-1 (10 x 5 = 50)

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

B_1 Three vectors **A B** & **C** whose scalar triple product is zero are coplanar. Justify.

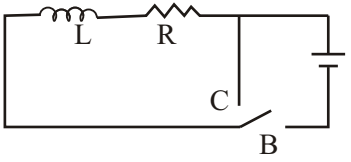
B_2 In an isothermal and isochoric process, the Helmholtz Free energy (F) of a thermo-dynamical system remains unaltered. Show.

B_3 Interference fringes formed by F P Etalon are sharper than those formed by Michelson Interferometer. Justify.

B_4 The concept of Bohr circular orbits does not violate Heisenberg uncertainty principle. Defend or refute.

B_5 The function $\Psi(x, t) = x^2 + c^2 t^2$ describes a one dimensional harmonic wave. Defend or refute

B_6 The total energy dissipated in an L R circuit when switch is turned from B to C is equal to the energy stored during one time constant just before turning the switch. Prove



B_7 When a neutron is absorbed by a target nucleus, the resulting compound nucleus is most likely to emit a gamma ray rather than a proton, deuteron or α-particle. Explain.

B_8 The frequency spread ($\Delta\nu$)of a spectral line is of the order of the inverse of coherence time (t_c). and the coherence length is $l_c = Q \times \lambda$ where Q is the purity factor & λ is the wave length. Justify.

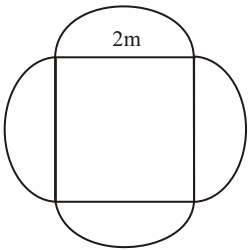
B_9 The spectra of alkali atoms differ from the spectrum of H_2. Explain

B_{10} The ratio of attractive magneto-static force (F_m) to the repulsive electrostatic force (F_e) between two protons running parallel with velocity v is $\frac{F_m}{F_e} = \frac{v^2}{c^2}$. Prove.

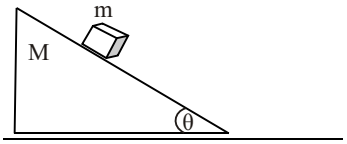
PART B-II (10 x 10 = 100)

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

P_1 Obtain an expression for the moment of inertia of the given lamina of mass M=5kg, having uniform surface density, about an axis perpendicular to its plane and passing through its centre of mass. The four semicircular sheets of radius R = 1 m are joined on each side of the square sheet of side length l = 2 m. Estimate the numerical value of the moment of inertia.



P_2 A small cubical block of mass m is placed on the smooth inclined plane of a wedge of mass M which in turn lies on a smooth horizontal surface. Obtain an expression for the acceleration of the wedge.



For what value of the wedge angle (θ) is this acceleration the maximum?

P_3 (a) A rock band gives rise to an average sound level of 105 db at a distance of 20 m from the centre of the band. As an approximation assume, that the band radiates sound equally in a hemisphere. Calculate the sound power output of the band.

(b) For a person with normal hearing, the faintest sound that can be heard at a frequency of 400 Hz has a pressure amplitude of $P_0 = 6.0 \times 10^{-5}$ Pa. Calculate corresponding intensity and sound intensity level at T = 293 K.

P_4 Show that the number of molecules having speed between v and v + dv in a random sample of N molecules of a classical ideal gas at temperature T is

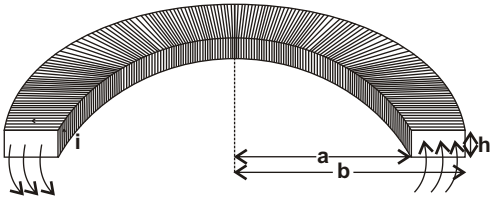
$$ndv = 4\pi N \left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}} dv.$$

Further establish that the maximum probable speed of molecules of such a Maxwellian gas is $v_m = \left(\frac{3}{2}\right)^{\frac{1}{2}} v_{rms}$. All symbols have their usual meaning.

P_5 While viewing a piece of sculpture behind a transparent glass sheet in a museum, one is often hindered by the glare (the light that is reflected off the front face of the glass sheet), and makes it difficult to see the

sculpture clearly. An expert has suggested a solution to reduce the glare to a minimum by coating the front surface of the glass sheet with a transparent thin film. If the refractive index of the sheet of flint glass is 1.62 (a) which material out of magnesium fluride (MgF_2, μ =1.38) or diamond (μ = 2.42) would you use for such a coating. (b) What is the minimum film thickness you need to deposit on glass sheet so as to minimize the glare if the light in use has a wave length λ = 5876 A°? (c) If this coating happens to be too thin to stand up to wear, what may be the possible thickness which you think would also work? Find only the three thinnest ones.

P_6 A toroid is obtained by winding N = 1000 close turns on an iron core (μ_r = 1240) of uniform rectangular cross - section of height h = 1cm. The inner and outer radii being equal to a = 5 cm and b = 10 cm as shown in the figure.



Show that its self inductance is expressed as $L = \frac{\mu_0 \mu_r N^2 h}{2\pi} \ln \frac{b}{a}$. Estimate the numerical value of L and the total flux linked when a current of 10A flows through it.

P_7(a) Show analytically that the formation of an image in a denser medium by a concave refracting surface is a consequence of the fact that 'light travels the path along which the time taken is the extremum.'

(b) Draw the Focal and Principal planes of Huygens eyepiece. Explain why Ramesden's eyepiece is preferred over this eye piece in all instruments used for physical measurements?

P_8 According to Fermi Dirac statistics the occupancy probability of an energy level of energy E is expressed as $f(E) = \frac{1}{e^{\frac{E-E_F}{kT}} - 1}$.

(a) Show that the occupancy probabilities of two energy states which are equally spaced (in energy) above and below the Fermi level add up to unity (one).

(b) At what temperature, one can expect a 10% probability that an electron in silver has an energy which is 1% above the Fermi Energy? The Fermi energy of silver is E_F = 5.5 eV.

P_9 Show that the commutator $\left[\frac{d}{dx}, V\right]$ is equivalent to $\frac{dV}{dx}$ where V=V (x) is the potential energy of the system. Further explore that the time evolution of a wave function $\Psi(x, t)$ of a quantum mechanical system is described by the equation $H\Psi = i\hbar \frac{d\Psi}{dt}$ where

$H = \left[-\frac{\hbar^2}{2m}\nabla^2 + V(r)\right]$ is the Hamiltonian of the system.

P_{10} Draw Thevenin and Norton equivalent circuit for the given network. Calculate current in a load impedance of 18Ω connected across terminals A & B in each case.