INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2010-11

Day and Date of Examination : Sunday, 23rd January 2011

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

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 forces is/are conservative force/forces?

(a) $F = x^2 i + y^2 j + z^2 k$

(b) $F = \nabla U$, U is Potential Energy

(c) $F = eE = -\frac{er}{2}\left(\frac{\partial B}{\partial t}\right)$, Force on a charge, due to induced electric field.

(d) $F = 6\pi\eta r v_t$ The viscous drag.

Q2. A metallic cube of edge length **l** = 1 m is stretched out uniformly by a force F normal to each of its faces. As a result the cube deforms to

(a) A cube of edge $L = 1 + \frac{F}{Y}[1-2\sigma]$

(b) A cube of edge $L = 1 - \frac{F}{Y}[1+2\sigma]$

(c) Volume strain $\frac{\Delta V}{V} = \frac{3F}{Y}[1-2\sigma]$

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Y and σ are Young's modulus and Poisson's ratio for the material.

Q3. What remains conserved when two light waves interfere?

(a) Intensity

(b) Amplitude

(c) Energy

(d) Phase

Q4. The excess pressure inside a soap bubble of radius R, having uniformly distributed charge q on its surface, is

(a) $\Delta p = \frac{2T}{R}$

(b) $\Delta p = \frac{4T}{R}$

(c) $\Delta p = \frac{4}{R}\left[T + \frac{q^2}{128\pi^2\varepsilon_0 R^3}\right]$

(d) $\Delta p = \frac{4}{R}\left[T - \frac{q^2}{128\pi^2\varepsilon_0 R^3}\right]$

Q5. A wire of length 25 cm carrying a current of 4.51 mA is folded into a circular coil and then placed in a magnetic field **B** = 5.71 mT. If the torque exerted on the coil is maximum

(a) The angle between the magnetic dipole moment and **B** must be 90

(b) The angle between the magnetic dipole moment and **B** must be zero.

(c) The wire must be folded just into a single turn.

(d) The maximum torque is 1.28×10^{-7} Nm.

Q6. Kepler's second law of planetary motion is a consequence of conservation of

(a) Area

(b) Energy

(c) Momentum

(d) Angular momentum

Q7. A Huygens' eyepiece has focal length F = 3cm. The separation between the two plano-convex lenses used in the eyepiece is

(a) 1 cm

(b) 2 cm

(c) 3 cm

(d) 4 cm

Q8. A Carnot engine takes in1000 k cal of heat at 627^0C and exhausts it to a sink at 27^0C

(a) The efficiency is 66.7%

(b) Work done is W= 2.8 M J

(c) Work done is W= 0.78 kWh

(d) Work done is W= 1.75 x 10^{19} MeV

Q9. An optical communication fibre is superior to a classical conducting copper wire because

(a) It maintains a high level of privacy

(b) It is immune to Electromagnetic induction (EMI) and Radio Frequency Interference (RFI)

(c) It has a wider frequency band width

(d) It is less hazardous as the signal is carried by photons

Q10. Nano-materials exhibit

(a) Large ratio of surface area to volume

(b) Remarkably distinct properties than those in macro/micro state

(c) Quantum confinement of carriers

(d) Faster movement of carriers

Q11. Ultrasonics are the mechanical waves whose

(a) Intensity is 100 watt/m^2

(b) Velocity varies with frequency

(c) Production is done by Piezo Electric effect

(d) Frequency lies between 20Hz and 20kHz

Q12. A small metallic sphere of mass m, having a charge q, is suspended by an inextensible and non-conducting thread such that it lies at a height h above a large metallic sheet lined on the floor. The tension in the string when it is vertical is just

(a) $mg + \frac{q^2}{4\pi\varepsilon_0 h^2}$

(d) $mg - \frac{q^2}{4\pi\varepsilon_0 h^2}$

(c) $mg + \frac{q^2}{16\pi\varepsilon_0 h^2}$

(d) $mg - \frac{q^2}{16\pi\varepsilon_0 h^2}$

Q13. The solution of differential equation

$$\frac{\partial^2\Psi}{\partial x^2} + \left(\frac{2m}{\hbar^2}\right)\left(E - \frac{1}{2}m\omega^2 x^2\right)\Psi = 0$$

of one dimensional harmonic oscillator is obtained / expressed in terms of

(a) Legendre Polynomial $P_n(x)$

(b) Bessel's Polynomial $J_n(x)$

(c) Hermite Polynomial $H_n(x)$

(d) Laugerre Polynomial $L_n(x)$

Q14 Diffraction patterns of monochromatic light of wavelength λ are formed by two gratings with same grating element but of different ruled width. In the two cases

(a) The resolving power is the same

(b) The dispersive power is the same

(c) The resolving power is different

(d) The dispersive power is different

Q15 An emitter follower is a transistor amplifier circuit with

(a) Common emitter

(b) Common collector

(c) Both output and input in phase

(d) Negative Feedback; gain less than 1.

Q16. In statistical mechanics the macro state of a system is described by the variables (T,N,V) and the density distribution function is expressed as $\rho = Ae^{-\varepsilon/KT}$. Such a description corresponds to

(a) Micro canonical ensemble

(b) Canonical ensemble

(c) Grand canonical ensemble

(d) Uniform ensemble

Q17. A paramagnetic salt ($FeCl_3$) has a dipole magnetic moment = 5.0 Am^2 at a temperature of 4 K in magnetic field of 1.0 T. The magnetic dipole moment of the same sample at 3 K in the magnetic field of 1.5 T will be

(a) 0.50 Am^2

(b) 5.0 Am^2

(c) 10.0 Am^2

(d) 15.0 Am^2

Q18. The mobility (μ) of electrons in copper with a free electron density $n = 9x10^{28} m^{-3}$ & electrical conductivity $\sigma = 6x10^7$ mho/m is

(a) $\mu = 1.064 \times 10^{-3} m^2 \Omega^{-1} C^{-1}$

(b) $\mu = 4.16 \times 10^{-3} m^2 \Omega^{-1} C^{-1}$

(c) $\mu = 1.064 \times 10^{-3} m^2 V^{-1} s^{-1}$

(d) $\mu = 4.16 \times 10^{-3} m^2 V^{-1} s^{-1}$

Q19. The energy eigen values of a particle in a one dimensional infinite potential well of width a are (n being the quantum number of state)

(a) $E_n \propto n^2$

(b) $E_n \propto n^{-2}$

(c) $E_n \propto a^{-2}$

(d) $E_n \propto a^2$

Q20. Maxwell's equations in E-M theory can be applied to

(a) Dielectric medium

(b) Conducting medium

(c) Plasma

(d) Free space (Vacuum)

Q21. Regular reoccurrence of peaks, for nuclei with atomic number A= 4,8,12….(i.e. at multiples of 4) in the curve of binding energy per nucleon for atomic nuclei, suggests

(a) Electron proton model of atomic nucleus

(b) An α-particle model of atomic nucleus

(c) Proton neutron model of atomic nucleus

(d) Tendency of these nuclei towards fusion

Q22. The interaction between the neighbouring dipoles, in absence of external magnetic field, is negligible in the case of a

(a) Diamagnetic material

(b) Paramagnetic material

(c) Anti-ferromagnetic material

(d) Ferromagnetic material

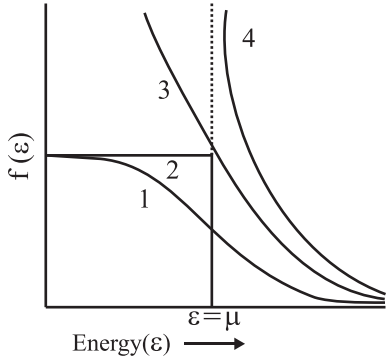
Q23. The Fermi Dirac distribution function for an ideal Fermi gas is plotted as f (ε)

(a) curve 1

(b) curve 2

(c) curve 3

(d) curve 4



Q24. The three axes of a crystal lattice are mutually perpendicular and its two lattice parameters are equal (a = b≠c). The crystal system is

(a) Monoclinic
(b) Tetragonal
(c) Orthorhombic
(d) Hexagonal

Q25. The Madelung constant for sodium chloride (NaCl) lattice is

(a) 1.7476
(b) 2.7476
(c) $[6-\frac{12}{\sqrt{2}}+\frac{8}{\sqrt{3}}-\frac{6}{\sqrt{4}}+.....]$
(d) $[6+\frac{12}{\sqrt{2}}-\frac{8}{\sqrt{3}}-\frac{6}{\sqrt{4}}+.....]$

Part B-1

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

B_1 The first time derivative of a vector of constant magnitude is always perpendicular to the vector itself. Show analytically.

B_2 With quantum considerations, the specific heat is a temperature dependent property of substances. Draw qualitatively an appropriate plot of the variation of the specific heat of a diatomic gas (H_2) over a temperature range from 50 K to 5000 K and explain.

B_3 Copper behaves as a good conductor for electro magnetic wave of frequency $\upsilon=10^{16}$hz (Ultraviolet) and as a dielectric for frequency $\upsilon=10^{20}$ Hz (X rays). Justify.

B_4 Fabry Perot interferometer and Lummer Gherkhe Plate are both multiple beam interferometers but the two produce different types of fringes. Comment and compare the fringes in the two cases.

B_5. "The small ozone layer on the top of the stratosphere is crucial for human survival." Explain why?

B_6 A convex lens and a zone plate have identical focusing action yet in contrast to a convex lens, a zone plate exhibits multiple foci. Justify

B_7 Eigen functions of a Hermitian operator belonging to different eigen values are orthogonal. Justify.

B_8 World wide transmission of a single T V program is not possible without a minimum of three satellites however a radio program is broadcasted all over the globe without the use of any satellite. Explain the difference?

B_9. What is luminescence? Explain how you would differentiate between fluorescence and phosphorescence?

B_{10} Under normal conditions of temperature, the electrical conductivity of a semiconductor increases with increase in temperature. However, in the high temperature range, a decrease in the conductivity is practically observed. Explain why?

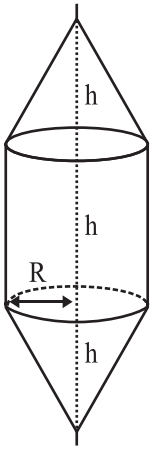
Part B-2

Solve all the following problems. Each carries 10 marks.

P(a) A glass capillary of sufficient length is vertically lowered to touch the free surface of water in a wide tank. Considering the wetting to be complete (angle of contact equal to zero), show that the heat liberated during the process of capillary rise is $dQ = \frac{2\pi T^2}{\rho g}$ where T and ρ are surface tension and density of water.

(b) A TV transmission tower has a height of 100 m. How much population is covered by the TV broad cast, if the average population density around the tower is 1000 per km^2? Consider earth as a uniform sphere of Radius $R = 6.37 \times 10^6$ m.

P2. In a simple hydrometer, two identical solid cones of height h are welded with a solid cylinder of same radius R and height h to form a composite structure of mass M. The whole mass is supported on a fine weightless wire stretched along the axis of cylinder as shown in figure.

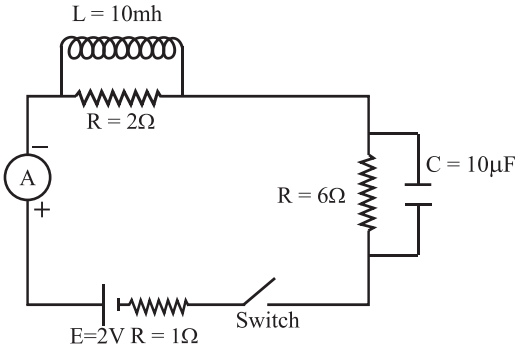


Obtain an expression for the moment of inertia, in terms of M and R, if the composite structure rotates about the wire.

P3(a). Earth receives W = 2 cal per minute per cm^2 solar energy in the form of light as an E– M wave in free space. Estimate the magnitude of electric field (E) and magnetic field (B) of electromagnetic radiation. Distance of sun from the earth is $r = 1.51 \times 10^{11}$ m.

(b). A LASER beam of 200 watt is concentrated by a convex lens into a cross section of 4×10^{-4} sq cm. Find the Poynting vector and the electric field of the E M wave so obtained.

P4. A resistance of 2Ω connected across an inductance of 10 mh and another resistance of 6Ω connected across a capacitor of 10μF are connected in series with a cell of emf 2 volt and internal resistance 1Ω.



Calculate the current just (i) when switched on (ii) long time after the switching on and (iii) when turned off.

P5. A dielectric slab with a spherical cavity of radius R, much greater than the molecular dimension, is placed between the plates of a charged capacitor. As a result, the dielectric slab gets polarized. If the polarization vector is **P** on the surface of the cavity, find the value of the electric field (E) produced at the center of the cavity.

P6. Show that the de Broglie wavelength (λ) of an electron of rest mass m_0 accelerated through a high electric potential of V volts is

$$\lambda = \frac{h}{\sqrt{2m_0eV\left(1+\frac{eV}{2m_0c^2}\right)}}$$

e being electron charge and c is velocity of light in vacum.

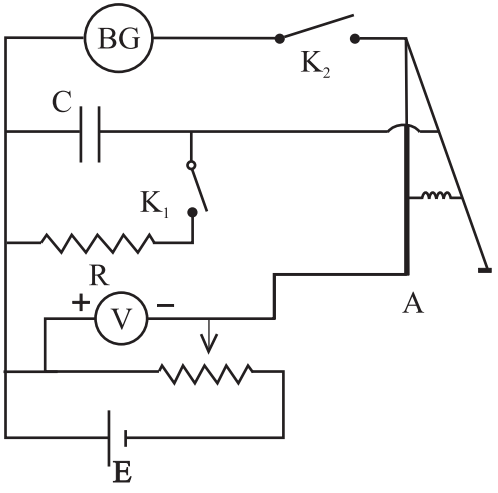
P7. At what rate angular momentum is being transferred to an object when a parallel beam of 100 watt circularly polarized light is incident normally on it? If the object is a

flat circular disc of diameter 5.0 mm and mass m = 10 mg, how long will it take to acquire an angular speed of 1.0 rev/sec (assuming it is free to rotate and was at rest initially)? The wavelength of light used is $\lambda = 500$ nm.

P8. How does the specific heat of solids vary at low temperature? What is Debye's explanation for such variation? Define Debye temperature for a solid. Gold is seen to have the similar structure as copper. The velocity of sound in gold and copper is respectively 2100 and 3800 m/s. Considering the Debye temperature (θ_D) for copper to be 348 K, estimate θ_D for gold. The respective densities and atomic weights are as given below.

$\rho_{Cu} = 8.96 \times 10^3 kg/m^3$, $\rho_{Au} = 19.3 \times 10^3 kg/m^3$ and $M_{Cu} = 63.54$ and $M_{Au} = 197.0$

P9 In an experiment with Ballistic Galvanometer the circuit is arranged as shown. The Morse key is pressed at A to charge the capacitor C = 0.1μF with a voltage V = 1.5 V. Releasing the Morse key and pressing the key K_2, the capacitor is discharged through BG and first (θ_1) and eleventh (θ_{11}) throws are noted. Again the capacitor is charged with the same voltage V= 1.5 V, Morse key is released and tapping key K_1 is pressed for time t=10s to discharge the capacitor through high Resistance R. Tapping key K_1 is released and K_2 is then closed correspondingly $\theta_1 = \theta_t$ is noted. The capacitor is again charged to same potential and left to itself for self leakage, with both keys open, for the same duration t=10S and then discharged through the BG by pressing K_2, $\theta_1 = \theta_{ts}$ is noted. The whole process is repeated for multiple observations for different values of time



(a) Develop a comprehensive theoretical formulation for the determination of high resistance (R) by this method of leakage.

(b) Show an expected plot of

$\ln\left(\frac{\theta_1}{\theta_t}\right)$ v/s t and $\ln\left(\frac{\theta_1}{\theta_{ts}}\right)$ v/s t.

(c) Calculate the value of R if the slopes of the two curves in (b) differ by 15^0 at a certain point where the former is π/4.

P10. The number of electron-hole pair in germanium is proportional to $e^{-\frac{E_g}{KT}}$, estimate the percentage change in the number of carriers in germanium ($E_g = 0.70$ eV) when temperature changes from 27^0C to 47^0C,

(b) An amplifier has an open loop gain (power gain) of 60 dB. If this gain changes by 20% due to aging effect, calculate the necessary feed back (closed loop gain) required to reduce this change only to 2%.

The key shall be available at www.indapt.org.in on 1.2.2011