PARLIAMENT OF INDIA

(JOINT RECRUITMENT CELL)

MAIN EXAMINATION FOR POSTS OF EXECUTIVE/LEGISLATIVE/COMMITTEE/PROTOC
OFFICER AND RESEARCH/REFERENCE OFFICER IN LOK SABHA SECRETARIAT

31st AUGUST, 2010

PHYSICS – PAPER- I

INSTRUCTIONS : Answers must be written in English only. Candidates should attempt at least 2 questions from each section and a total of 5 questions. The number of marks carried by each question is indicated against the same.

Time : 3 hours **Marks : 300**

SECTION – A

1. (a) A bomb explodes in flight into two fragments when its velocity is $10\hat{i} + 2\hat{j}$. If the smaller mass M flies with velocity $20\hat{i} + 50\hat{j}$, deduce the velocity of the larger mass 3M. Deduce also the velocities of the fragments in the centre of mass reference frame. (30 Marks)

   (b) A rocket, set for vertical firing, weighs 50kg and contains 450kg of fuel. It can have a maximum exhaust velocity of 2 km/sec. What should be its minimum rate of fuel consumption to just lift it off the launching pad? (20 Marks)

   (c) Show that the angular momentum of a particle moving under the influence of a central force always remains conserved. (10 Marks)

2. (a) Find the moment of inertia of a solid sphere about its diameter. (30 Marks)

   (b) Derive parallel axis theorem. Use this to find the moment of inertia of a sphere about a tangent to the sphere. (20 Marks)

   (c) What is a gyroscope ? Explain its working and mention some of its applications. (10 Marks)

3. (a) Find the resultant of two plane simple harmonic waves of the same period travelling in the same direction but differing in phase and amplitude. What is the amplitude of the resultant wave if these waves have amplitudes 3 cm and 4 cm and their phase difference is 90°? (30 Marks)

   (b) Explain the difference between phase and group velocities. Under what conditions these are equal. Give examples. (20 Marks)

   (c) A 75 cm string is stretched between fixed supports. It is observed to have resonant frequencies of 420 and 315 Hz, and no other resonant frequencies between these two. What is the lowest resonant frequency for this string? (10 Marks)

4. (a) Explain the basic postulates of Special theory of relativity. Derive Lorentz transformation equations. (30 Marks)

   (b) Calculate the percentage contraction in the length of a rod in a reference frame, moving with a velocity 0.8c in a direction at an angle of 30° with its length. (20 Marks)

   (c) Show that a four-dimensional volume element is a Lorentz invariant. (10 Marks)

5. (a) A grating has 8200 lines uniformly spaced over 25.4 mm and is illuminated by light from mercury vapour discharge. What is the expected dispersion , in third order, in the vicinity of the intense green line(λ=546 nm) ? Also find the resolving power of this grating in the fifth order. (30 Marks)

   (b) Derive the law of reflection and Snell's law from Format principle. (20 Marks)

   (c) Two polarizing sheets have their polarizing directions parallel so that the transmitted intensity of the light is maximum. Through what angle must either sheet be turned if the intensity is to drop by half of the maximum? (10 Marks)

SECTION – B

6. (a) Consider a point charge +Q at a distance D to the left of an infinite conducti... which is connected to earth. Use the method of images to obtain the induced charge d... on the surface of the conducting plane. (30 Mar...

(b) A spherical charge distribution is given by

$$\rho = \rho_0 [1-(r/a)^2] \quad ; \ (r \leq a)$$
$$\rho = 0 \quad ; \ (r > a)$$

Calculate the total charge Q. (20 Marks)

(c) Explain the hysteresis loop with a diagram. (10 Marks)

7. (a) Derive critical constants for a real gas obeying Van der Waal equation. (30 Marks)

(b) For a Maxwell-Boltzmann distribution of molecular velocities, calculate the average speed and the most probable speed of the molecules. (20 Marks)

(c) Explain the process of adiabatic demagnetization. (10 Marks)

8. (a) Show that Bose-Einstein condensation does not take place in one dimension. (30 Marks)

(b) At what wavelength will the human body (assumed to be a perfect blackbody) radiate the maximum radiation? Estimate the total power radiated by a person of medium built (assume an area given by a cylinder of 165 cm height and 90 cm radius)? (20 Marks)

(c) Explain the concept of negative temperature. Also explain the meaning of Planck length, Planck time and Planck temperature. (10 Marks)

9. (a) Twelve resistors, each of resistance R ohms, form a cube. Find the equivalent resistance of a face diagonal. (30 Marks)

(b) A circular UHF television antenna has a diameter of 10 cm. The magnetic field of a TV signal is normal to the plane of the loop and, at a given instant of time, its magnitude is changing at the rate of 0.15 T/s. The field is uniform. What is the emf in the antenna? (20 Marks)

(c) A surveyor is using a magnetic compass 5m below a power line in which there is a steady current of 100A. Will this interfere seriously with the compass reading? The horizontal component of the earth's magnetic field at the site is 20μT. (10 Marks)

10. (a) Write down Maxwell's equations and give their physical interpretation. Show how Ampere's law is modified to be consistent with the equation of continuity. Reduce Maxwell's equations in terms of scalar and vector potentials. (30 Marks)

(b) What are gauge transformations? Show that electric and magnetic field vectors are gauge invariant. (20 Marks)

(c) Explain the process of Rayleigh scattering. (10 Marks)

Useful constants: Wien's displacement law constant: 2.898×10^{-3} m.K
Stefan–Boltzmann constant $= (5.67 \times 10^{-8}$ W/m^2.K$^4)$
Permeability constant $= 1.26 \times 10^{-6}$ T.m/A

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31st AUGUST, 2010

PHYSICS PAPER - II

INSTRUCTIONS: Attempt FIVE questions in all. Choose at least two questions each from Sections A & B. Symbols have their usual meanings.

Time: 3 Hours **Maximum Marks: 300**

Given constants: Mass of proton = 1.6725×10^{-27} kg = 938.26 MeV
Mass of neutron = 1.6748×10^{-27} kg = 939.55 MeV;
Mass of electron = 9.1091 x 10-31 kg = 511.01 keV
h = 6.6256 x 10-34 J-s; h/cut = 6.582 x 10-22 MeV –sec.
Atomic mass of ^{15}N = 15.000109 ; Atomic mass of ^{15}O = 15.003065

SECTION - A

1. (a) Why do we need to normalize the wave function? Is normalization factor time dependent?
(b) Calculate the probability current S corresponding to the wave function
Examine S for large values of r and interpret the results.
(c) Describe the salient features of WKB approximation. Describe how it can be used for life time calculation in alpha decay of nuclei. What are the limitations of method? **(10, 20, 30 Marks)**

2. (a) Define and obtain an expression for Fermi energy for a free electron gas in a metal. The density of copper is 8.96 gm/cm^3 and atomic mass is 63.5 gm/mole. Calculate the Fermi energy.
(b) What is zero point energy? Discuss its physical significance.
(c) (i) Show explicitly that for any two vectors **A** & **B**

$$(\boldsymbol{\sigma}.\mathbf{A})\,(\boldsymbol{\sigma}.\mathbf{B}) = \mathbf{A}.\mathbf{B} + i\,\boldsymbol{\sigma}.(\mathbf{A} \times \mathbf{B})$$

Where $\boldsymbol{\sigma}$ are Pauli's matrices.

(ii) For any function f(x) show that

$$[\boldsymbol{p}, f(x)] = ih\frac{\partial f(x)}{\partial x}$$, where **p** is momentum operator. **(30, 10, 20 Marks)**

3. (a) The uncertainty relation $\Delta x.\ \Delta p_y = 0$ is (i) always true or (ii) always false or (iii) true or false depends upon physical conditions. Justify your answer.
(b) Describe an effect that accounts for the separation of D-lines of sodium spectrum.
(c) The term symbol for particular state of three different atoms are quoted as $^4S_1$, $^2D_{7/2}$, and $^0P_1$. Explain why these are erroneous.
(d)What are limitations of L.S coupling? **(10, 10, 30, 10 Marks)**

4. (a) Analyze the Zeeman effect for the n =2 state of hydrogen in weak, strong & intermediate magnetic field regions. Plot energies as function of external field. Show explicitly that intermediate field results reduce properly in the two limiting cases.
(b) The term symbols for a particular atom is $^4D_{5/2}$. What are the values for L, S & J for this state? What is the minimum number of electrons which could give rise to this? Suggest a possible electronic configuration. **(30, 30 Marks)**

5. (a) With what type of spectroscopy would one observe the pure rotational spectra of H
If the bond length of H_2 is 0.07417 nm, what would be the spacing of the lines in the spectrum? The spin of the hydrogen nucleus is ½ h, does this make any difference to the answer?
(b) $J=0 \rightarrow J=1$ rotational absorption line occurs at 1.153×10^{11} Hz in $^{12}C^{16}O$ and at 1.102×10^{11} Hz in $^{?}C^{16}O$. Find the mass number of unknown carbon isotope.
(c) State the selection rules for Raman spectroscopy.
(d) Discuss the basic principle of NMR. Describe some of its industrial applications.
(20, 10, 10, 20 Marks)

SECTION - B

6. (a) A simplified model of deuteron consists of a neuron and a proton in a square potential well 2 fm in radius and 35 MeV depth. Is this model consistent with uncertainty principle?
(b) Find the activity of 1.00 mg of radon, $222R_N$ (atomic mass 222 & $T_{1/2} = 3.82$ days).
(c) Outline the salient features for Shell model. Comment on its limitations.
(d) Write a short note on breeder reactor. Discuss its significance in the context of Indian nuclear energy program. **(10, 10, 20, 20 Marks)**

7. (a) What limits the size of a stable nucleus? Which of the nucleus would you expect to be stable : (i) $^{7}_{3}Li$ or $^{8}_{3}Li$; (ii) $^{12}_{6}C$ or $^{13}_{6}C$?
(b) Find minimum kinetic energy in laboratory frame a proton must have to initiate the reaction $^{15}N(p,n)^{15}O$.
(c) What do you understand by the term ***spallation***? Discuss using suitable example.
(d) Discuss basic principle of Mossbauer spectroscopy. Discuss some of its important applications. **(20, 10, 10, 20 Marks)**

8. (a) Name different quark flavors. Discuss their main properties. Write the quark contents of p, π^+, K^0, Ξ^0, Λ.
(b) Name the field quanta of weak and strong interactions. Compare their properties with those of photons.
(c) Describe important properties of neutrinos. How would we experimentally distinguish between neutrino and antineutrino?
(d) What do you understand by **Grand Unification** of fundamental forces of nature? Is there any experimental evidence in support of this? **(10, 20, 10, 20 Marks)**

9. (a) What are *Miller indices*? What is their physical significance? Draw 110 and 111 planes for a simple cubic crystal structure.
(b) What are Cooper pairs? Discuss their characteristic properties.
(c) Describe with the help of diagram the Fermi energy in intrinsic and doped p & n semiconductor.
(d) Write short note on ***thermistors***. **(20, 10, 10, 20 Marks)**

10. (a) Write truth table for a 3-input AND, OR, NAND and Nor logical gates.
(b) Explain difference between ac and dc load lines. Derive the load line of a BJT in CE configuration.
(c) Write short notes on (i) 8085A Microprocessor, (ii) Comparison of JFET and MOSFET.
(d) Write truth table for a 3-bit Parity checker and design the circuit. **(20, 10, 20, 10 Marks)**

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