Civil Services (Main) Examination, 2015

PHYSICS
(Paper II)

Time Allowed : Three Hours **Maximum Marks : 250**

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.
Candidate has to attempt FIVE questions in all.
Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.
The number of marks carried by a question/part is indicated against it.
Wherever any assumptions are made for answering a question, they must be clearly indicated.
Word limit in questions, wherever specified, should be adhered to.
Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

SECTION 'A'

1. (a) Obtain an expression for the probability current for the plane wave $\psi(x,t)=\exp[i(kx-\omega t)]$. Interpret your result. **10**

(b) Using dimensional analysis, explain why the angular momentum of a particle cannot be $\hbar^2$. **10**

(c) Two successive lines in the rotational emission spectrum of HCl molecule appear at wave numbers 83.5 cm^{-1} and 104.1 cm^{-1}. Calculate the position of the next line appearing at the higher wave number. **10**

(d)(i) Establish that:

$$hc=1240 \text{ eV.nm}=1240 \text{ MeV. fm}$$ **5**

(d)(ii) The energy levels of a hydrogen atom are given by $E_n=((-1)/n^2)R_{yd}$ where $1\ R_{yd}=hcR$. Show that $R=1.097\times10^7\ m^{-1}$. **5**

(e) If K, L and M energy levels of platinum are approximately 78, 12 and 3 keV, respectively, below the vacuum level, calculate the wavelengths of K_α and K_β lines. **10**

2. (a) Solve the Schrödinger equation for a particle in a three dimensional rectangular potential barrier. Explain the terms degenerate and non-degenerate states in this context. **30**

(b) Write the time independent Schrödinger equation for a bouncing ball. **10**

(c) Normalized wave function of a particle is given below:

$$\psi=N\exp((-x^2)/2a^2+ikx).$$

Find the expectation value of position. **10**

3. (a) What is Zeeman effect? How can it be understood on the basis of quantum mechanics? **25**

(b) Obtain Zeeman splitting for sodium D-lines. **15**

(c) Find the magnetic moment of an atom in $3P_2$ state, assuming that LS coupling holds for this case. **10**

4. (a) Hydrogen molecule is diatomic. Obtain the rotational energy levels of this molecule. Write down the selection rules. Obtain the smallest energy required to excite the lowest rotational mode. **30**

(b) The observed vibrational frequency of CO molecule is 6.42×10^{13} Hz. What is the effective force constant of the molecule? **10**

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(c) A particle trapped in an infinitely deep square well of width a has a wave function $\psi=(2/\pi)^{1/2}\sin(\pi x/a)$. The walls are suddenly separated by infinite distance. Find the probability of the particle having momentum between p and p+dp. **10**

SECTION 'B'

5. (a) Define Q of a reaction. Calculate the Q-value of the reaction:

$$^{9}_{4}\mathrm{Be}(^{4}_{2}\mathrm{He}, n)^{12}_{6}\mathrm{C}.$$

Given: Mass (^{9}Be) = 9.012183 u Mass (^{4}He) = 4.002603 u Mass (^{12}C) = 12.000 u. **10**

(b) Show that any arbitrary rotation axis is not permitted in a crystal lattice. **10**

(c) State the quantum numbers I_z, Y and S for uds quarks and antiquarks. Which combination of these leads to the formation of a (i) proton and (ii) neutron? **10**

(d) Simplify the logical expression $[A\bar{B}(C+BD)+\bar{A}\bar{B}]C$. **10**

(e) Differentiate between n-p-n and p-n-p transistors. Give their device structure and biasing circuits when used as an amplifier. **10**

6. (a) Describe grand unification theories (GUT). **20**

(b) How many types of neutrinos exist? How do they differ in their masses? **15**

(c) Write down the following decays in terms of quarks: (i) $\Omega^- \rightarrow \Lambda + K^-$ (ii) $\Lambda \rightarrow p+\pi^-$ (iii) $K^- \rightarrow \mu^- + \nu_\mu$. **15**

7. (a) Design a transistor based Colpitt oscillator which can oscillate at 9 MHz. Explain how the oscillations are created and sustained. **15**

(b) Describe an operational amplifier based integrator. Using operational amplifier integrators, design a circuit to solve the following differential equation:

$$d^2v/dt^2+2dv/dt+3v=0.$$ **20**

(c) Draw the device structure of a p-n junction solar cell and explain how light energy is converted into electrical energy. Draw and explain its I-V characteristics. **15**

8. (a) Find an expression for lattice specific heat of a solid, and its low and high temperature limits. What is Debye temperature? **20**

(b) Describe the motion of an electron in one dimensional periodic potential and show that it leads to formation of bands of allowed and forbidden states in the electron energy spectrum. How are the conductors, semiconductors and insulators discriminated on the basis of band structure? **20**

(c) Distinguish between a superconductor and perfect conductor. Explain what is a Cooper pair. **10**

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