Indian Forest Services (Main)
Examination-2025

DJSM–B–PHYS

PHYSICS

PAPER—II

Time Allowed : Three Hours

Maximum Marks : 200

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are EIGHT questions in all, out of which FIVE are to be attempted.

Question Nos. **1** and **5** are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections A and B.

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.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

Answers must be written in ENGLISH only.

Useful Constants :

Mass of proton	=	$1 \cdot 673 \times 10^{-27}$ kg
Mass of neutron	=	$1 \cdot 675 \times 10^{-27}$ kg
Mass of electron	=	$9 \cdot 11 \times 10^{-31}$ kg
Planck constant	=	$6 \cdot 626 \times 10^{-34}$ J s
Boltzmann constant	=	$1 \cdot 380 \times 10^{-23}$ J K^{-1}
Bohr magneton (μ_B)	=	$9 \cdot 273 \times 10^{-24}$ A m^2
Nuclear magneton (μ_N)	=	$5 \cdot 051 \times 10^{-27}$ J T^{-1} (A m^2)
Electronic charge	=	$1 \cdot 602 \times 10^{-19}$ C
Atomic mass unit (u)	=	$1 \cdot 660 \times 10^{-27}$ kg
	=	931 MeV

g_s^p	=	$5 \cdot 5855\ \mu_N$	$m(p)$	=	$1 \cdot 00727$ u
$m(n)$	=	$1 \cdot 00866$ u	$m(^4_2\text{He})$	=	$4 \cdot 002603$ u
$m(^{12}_6\text{C})$	=	$12 \cdot 00000$ u	$m(^{87}_{38}\text{Sr})$	=	$86 \cdot 908893$ u
$m(^2_1\text{H})$	=	$2 \cdot 014022$ u	$m(^3_1\text{H})$	=	$3 \cdot 0160500$ u
$m(^{16}_8\text{O})$	=	$15 \cdot 999$ u			
$\hbar$	=	$1 \cdot 05 \times 10^{-34}$ J s			
$\hbar c$	=	197 eV nm			

SECTION—A

1\. (a) A particle is described by the wave function $\psi(x, t) = e^{i(kx - \omega t)}$.

(i) Is this wave function an eigenfunction corresponding to any dynamical variable or variables? If so, name the variable(s). 6

(ii) Does this represent a ground state? 2

(b) The raising (J_+) and lowering (J_-) operators are defined by $J_+ = J_x + iJ_y$ and $J_- = J_x - iJ_y$. Show that—

(i) $[J_z, J_\pm] = \pm \hbar J_\pm$

(ii) $J_+ J_- = J^2 - J_z^2 + \hbar J_z$ 8

(c) A bullet of mass 0·025 kg is moving with a velocity of 600 m/s. The speed is measured with an accuracy of 0·02%. Find out the uncertainty in x. Also, comment on the result. 6+2

(d) Why were silver atoms used in Stern-Gerlach experiment? Also, write the importance of this experiment. 8

(e) (i) Discuss the importance of studying the isotope effect in rotational spectroscopy. 4

(ii) If hydrogen is substituted by deuterium in hydrogen molecule, calculate the change in rotational constant B. 4

2\. (a) Explain the phenomenon of penetration of a particle through a barrier whose height exceeds the total energy of the particle with necessary diagram. 15

(b) An alpha particle is trapped in a nucleus of radius 1·4 fm. What is the probability that it will escape from the nucleus if its energy is 2 MeV? The potential barrier at the surface of the nucleus is 4 MeV. [Given : The mass of the alpha particle is $6 \cdot 64 \times 10^{-27}$ kg] 10

(c) (i) Derive an expression for density of states for a free electron gas in one dimension. Hence, show its variation with energy for a one-dimensional metallic crystal. 9+3

(ii) Where do you find the applications of free electron gas model? 3

3\. (a) Write the electronic configurations for carbon (C), nitrogen (N) and oxygen (O) atoms, and then derive their ground states. 15

(b) Experimental observation for the line spectrum of an atom shows that the separations between adjacent energy levels of increasing energy in a multiplet are in the ratio 3 : 5. By using the Landé interval rule, assign the quantum numbers L, S and J to these levels. 15

(c) If ^{11}Na atoms in their ground state are placed in a region having electromagnetic radiation of frequency $\nu = 1 \cdot 0 \times 10^{10}$ Hz, calculate the required magnetic field B at which the electromagnetic radiation will be in resonance with the Zeeman splitting. 10

4. (a) (i) With suitable diagrams, explain the intensity distribution of spectral lines in vibrational-electronic spectra by using the Franck-Condon principle. 15

(ii) Calculate the positions of the first two rotational Raman lines in the spectrum of H_2, if its bond length is $0 \cdot 074$ nm. [Given : $^1H = 1 \cdot 673 \times 10^{-27}$ kg] 5

(b) Explain the salient features of fluorescence and phosphorescence with the help of energy level diagram. Name a few applications of these phenomena in our daily life. 7+3

(c) Obtain the resonance condition of nuclear magnetic resonance spectroscopy. Write down at least three important applications. 7+3

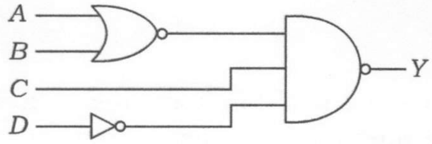
SECTION—B

5. (a) Calculate the minimum energy (E_γ) required for a gamma ray photon to disintegrate a deuteron of mass M and binding energy B into a neutron and a proton. (Assume $B << Mc^2$) 8

(b) If plutonium ($^{239}_{94}$Pu) is used as fuel in a fission reactor and is producing fragments barium ($^{146}_{56}$Ba) and strontium ($^{91}_{38}$Sr) by initiating the reaction by one neutron and producing three neutrons in the process, then calculate the number of fissions per second required in a 100 MW reactor. [Given : BE per nucleon (MeV) : $7 \cdot 6$ for ^{239}Pu, $8 \cdot 2$ for ^{146}Ba and $8 \cdot 6$ for ^{91}Sr] 8

(c) What is a microprocessor? Briefly mention the basic units of a microprocessor by drawing descriptive block diagram of 8085 microprocessor. 8

(d) What is Boolean algebra? State De Morgan's theorems and determine the output expressions for the circuit shown below by using De Morgan's theorems :



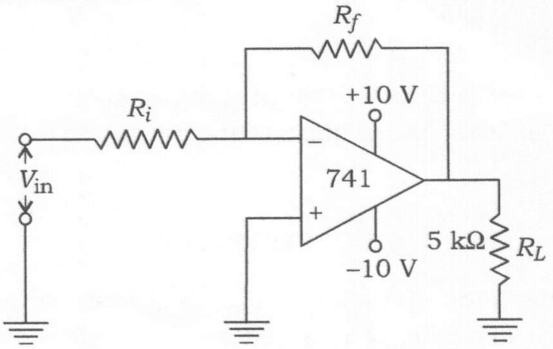
8

(e) What is Josephson effect? How can Josephson junctions be used to produce macroscopic quantum interference? 8

6. *(a)* By considering a suitable nuclear potential well for the deuteron ground state, show that it is a loosely bound nucleus. 20

(b) Consider an energy band which is filled with electrons up to a certain value $k_1\left(k_1 < \dfrac{\pi}{a}\right)$. Determine the total effective number of free electrons in the energy band. Comment on the electron distribution in an insulator, intrinsic semiconductor and metals at 0 K. Symbols have their usual meanings. 10

(c) Describe the bandwidth and slew rate of an Op-Amp. The amplifier shown in the below circuit is used to amplify an input signal to a peak output voltage of 100 mV and its slew rate is $0 \cdot 5$ V/μs. What is the maximum operating frequency of the amplifier?



10

7. *(a)* What do you understand by SU(3) symmetry for the quark model? On the basis of it, explain that the baryons can have +2 charge but mesons cannot have the same. 10

(b) *(i)* Explain the Bravais lattice and non-Bravais lattice with suitable diagram. 10

(ii) Draw the (1 0 0), (1 1 0) and (1 1 1) planes in a cubic unit cell. 5

(iii) Obtain the Miller indices of a plane with intercepts a, $b/2$, $3c$ in a simple cubic unit cell. 5

(c) What is an oscillator? Explain the Barkhausen criterion and working principle of an *R-C* phase-shift oscillator with suitable circuit diagram. 10

8. *(a)* Using the semi-empirical binding energy formula, establish the relation between atomic number and mass number for a most stable light nucleus. Also, explain which is the most stable nucleus among ${}_2^3\text{He}$, ${}_4^6\text{Be}$ and ${}_3^6\text{Li}$. [Given : $a_c = 0 \cdot 71$ MeV, $a_n = 22 \cdot 7$ MeV and assume $Z(Z-1) \simeq Z^2$] 10

(b) (i) Give a qualitative description of the BCS theory and explain how it accounts for the superconducting state. 10

(ii) The critical field of niobium is 1×10^5 A/m at 8 K and 2×10^5 A/m at absolute zero. Find the transition temperature of the element. 5

(c) (i) How will you obtain OR gate from NAND gate? Draw the logic circuit for the following expressions :

$$Y = ABC + \overline{D}$$
$$Y = (\overline{E}G + B)H$$
10

(ii) What is a thermistor? Explain the working of thermistor by drawing temperature-resistance curve. 5

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