

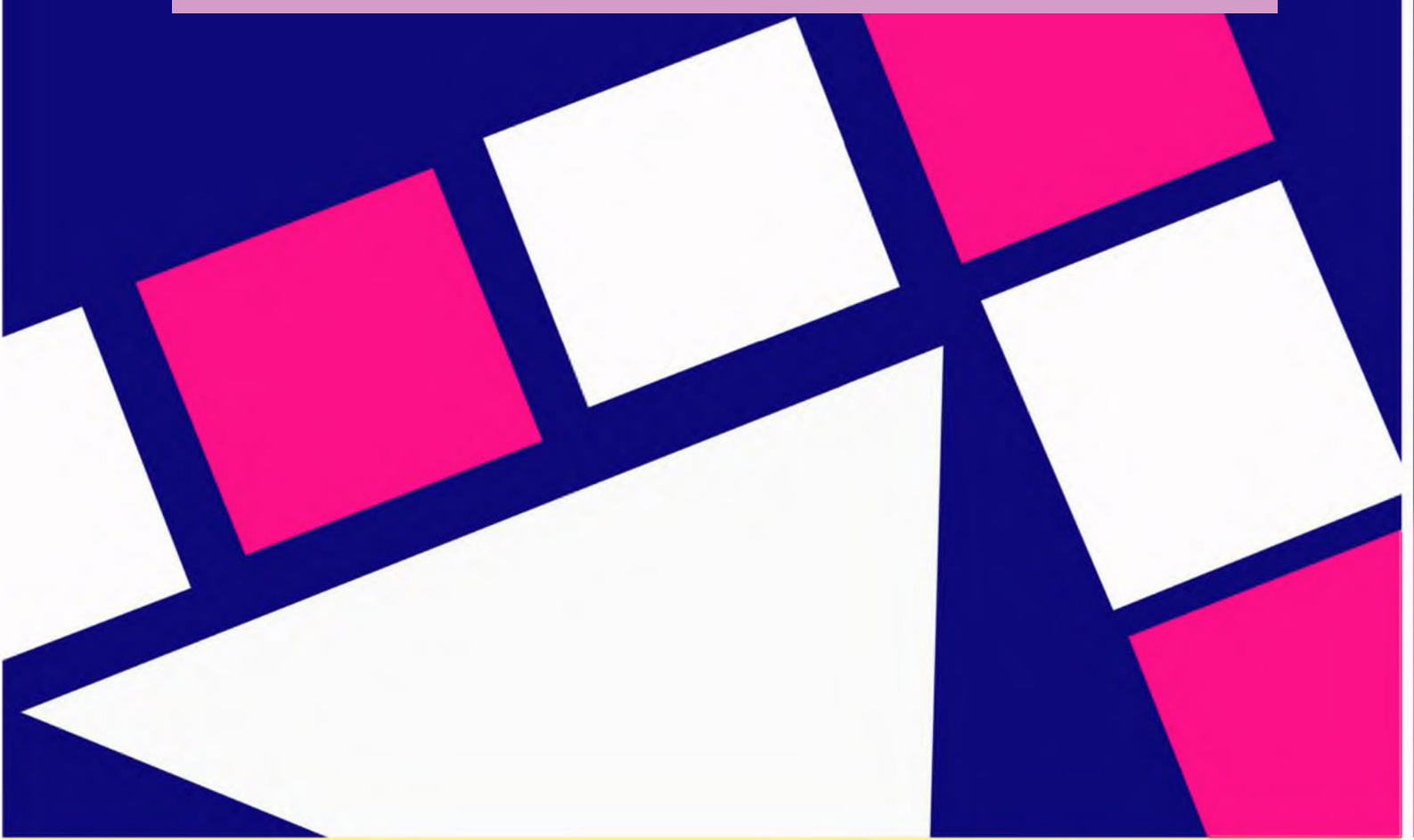
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## **Online IAS Academy**

### **PHYSICS - Optional**

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**Atomic & Molecular Physics 2015 - 2019**



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## UPSC – PHYSICS Optional – 2015 Questions

1. Two successive lines in the rotational emission spectrum of HCl molecule appear at wave numbers  $83.5 \text{ cm}^{-1}$  and  $104.1 \text{ cm}^{-1}$ . Calculate the position of the next line appearing at the higher wave number. [10M]
2. 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  $K_\alpha$  and  $K_\beta$  lines. [10M]
3. What is Zeeman effect? How can it be understood on the basis of quantum mechanics? [25M]
4. Obtain Zeeman splitting for sodium D-lines. [15M]
5. Find the magnetic moment of an atom in  $3P_2$  state, assuming that LS coupling holds for this case. [10M]
6. 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. [30M]
7. The observed vibrational frequency of CO molecule is  $6.42 \times 10^{13}$  Hz. What is the effective force constant of the molecule? [10M]

## UPSC – PHYSICS Optional – 2016 Questions

1. In the Stern-Gerlach experiment using Ag atoms, the oven temperature is 1000 K,  $l \approx 25$  cm and  $\frac{\partial B_z}{\partial z} \approx 10^{+3}$  Tesla/m. Calculate the separation of the two components. [10M]
2. Describe Stern - Gerlach experiment. Discuss how it has explained space quantization and electron spin. Find the value of angle between the spin angular momentum  $\vec{S}$  and its z-component of an electron moving along the external magnetic field  $\vec{B}$ . [10M]
3. The series limit wavelength of Balmer series in hydrogen spectrum is experimentally found to be  $3646 \text{ \AA}$ . Find the wavelength of the first line of this series. [10M]
4. Compute the allowed spectral terms for two non-equivalent p-electrons on the basis of Pauli's exclusion principle. [10M]
5. What is Raman effect? Describe briefly the chief characteristics of pure rotational spectra. The small rotational Raman displacement for HCl molecule is  $41.6 \text{ cm}^{-1}$ . Find the internuclear distance between the atoms forming the molecule. [10M]
6. Explain in detail L-S coupling and j-j coupling schemes. [10M]
7. What is Lamb shift? What is its significance in determining the fine structure of  $H_\alpha$  Balmer line in hydrogen atom? [10M]

## UPSC – PHYSICS Optional – 2017 Questions

1. Estimate the de Broglie wavelength of the electron orbiting in the first excited state of the hydrogen atom. [10M]
2. Show that the lines in the absorption spectra corresponding to the rotational transitions from two adjacent energy levels of a medium sized molecule at room temperature have comparable intensities. [10M]
3. Given the force constant of HCl molecule =  $516 \text{ Nm}^{-1}$ , determine the wave number of the fundamental mode of vibration of the molecule. How many transition lines one can expect in the vibration spectra of HCl molecule at room temperature ? [10M]
4. Explain Stokes and anti-Stokes Raman scattering with the help of energy level diagram. For a diatomic molecule, obtain expressions for transition energies of its Raman spectra with rotational fine structure and hence the wave numbers of the Stokes lines. [20M]
5. Explain why lines in some Raman spectra are found to be plane polarized to different extents even though the exciting radiation is completely unpolarized ? [10M]
6. State Franck-Condon principle. Define Franck-Condon factors. Using schematic diagram, explain the decay of excited states leading to the phenomena of fluorescence and phosphorescence. [20M]
7. Explain the principle of Nuclear Magnetic Resonance (NMR) with the help of an energy level diagram. Give examples of nuclei which exhibit NMR. What major inferences can be drawn from an NMR spectra ? [20M]
8. In an NMR experiment, hydrogen atoms are subjected to a magnetic field of 5.0 T. Determine the difference in energy (kJ/mol) between two spin states of the nuclei of hydrogen atom and the frequency of radiation required for NMR. [15M]

## UPSC – PHYSICS Optional – 2018 Questions

1. What is nuclear precession? How is it used in the principle of working of an NMR? [10M]
2. The ground state wave function for hydrogen atom is

$$\varphi(r) = \frac{1}{\sqrt{\pi a_0^3}} e^{-r/a_0}$$

Where  $a_0$  is the Bohr radius. Sketch the wave function and the probability density as a function of the separation distance  $r$ . Calculate the probability that the electron in the ground state is found beyond the Bohr radius. [20M]

3. Describe the importance of L-S and J-J coupling in atomic spectroscopy. What are experimental evidences of their existence? [20M]
4. What is Zeeman effect? Discuss the factors on which Larmor frequency is dependent. [15M]
5. Discuss the fine structure of hydrogen spectrum. How is it of importance in the astronomical observations? [15M]
6. Discuss the theory of rotational and vibrational spectra of diatomic molecules. What is the difference between fluorescence and phosphorescence? [20M]

### UPSC – PHYSICS Optional – 2019 Questions

1. Why is population inversion in general not possible in a two-level laser system? Explain it [10M]
2. Why are Raman active vibrations and IR vibrations in  $CO_2$  molecule complementary to each other? [10M]
3. Define mathematically the Bohr radius of a hydrogen atom and show that the binding energy at state  $n$  of this atom can be given by

$$E_n = -\frac{1}{2} \frac{Ze^2}{(a/Z)} \frac{1}{4\pi^2\pi\epsilon_0}$$

Where  $Z$  is the atomic number of H atom. Calculate the numerical values of  $a$  and  $E_1$  of H atom. [15M]

4. Estimate the size of hydrogen atom and the ground state energy from the uncertainty principle. [15M]
5. Describe normal and anomalous Zeeman effect. Explain how it lifts the degeneracy in hydrogen atom. [20M]
6. What is Lamb shift? Discuss its significance in determining the fine structure of  $H_\alpha$  Balmer line in hydrogen atom. [15M]
7. What is Franck-Condon principle? Discuss the intensity distribution in the vibrational electronic spectra of a diatomic molecule on the basis of this principle. [15M]

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