RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. SIXTH SEMESTER TAKE-HOME TEST / ASSIGNMENT, JULY 2020

THIRD YEAR [BATCH 2017-20]

Starting Date & Time : 11/07/2020 at 11 a.m. **PHYSICS (Honours)**

Closing Date & Time : 12/07/2020 at 11 a.m. **Paper : VIII & IX** Full Marks : 50+50

Paper : VIII

Answer all the questions [5×10]

Group – A

1. An EM-wave in source-free vacuum has the field functions as follows:

$$\vec{E}(\vec{r},t) = \hat{e}f(\vec{r}.\hat{n} - ct)$$

$$\vec{B}(\vec{r},t) = \hat{h}g(\vec{r}.\hat{n} - ct)$$

If the wave travels along the direction of the vector, $\vec{b} = 4\hat{i} - 3\hat{j} + 12\hat{k}$.

a) Write the fields in terms of *(x,y,z,t)* .

b) Show that the fields are transverse and find a relation between *f* and *g.*

c) If $\hat{e}$ lies in the x-y plane(with *x,y* positive), find $\hat{e}$ and $\hat{h}$.

d) Hence describe the nature of the wave. [1+2+1+1]

2. a) Obtain an expression for the intensity of a plane EM wave in free-space.

b) Radiation from the sun falls on the surface of the earth at a rate 2.0 Cal/cm^2 /min. i) Find the magnitude of the Poynting vector(W/m^2) in sunlight. (ii) Find the magnitudes of r.m.s electric and magnetic fields in sunlight with proper units. (iii) What is the power output of the sun in the form of sunlight alone? (1 cal = 4.18J, earth-sun distance= 1.5×10^{11} m) [2+3]

3. A plane EM wave of angular frequency ω is incident from vacuum on the plane surface of a non-magnetic metal of conductivity σ and permittivity ε, along the normal to the interface.

a) Choosing $+\hat{z}$ as the incident direction, write down expression for the incident, reflected and transmitted waves(both $\vec{E}$ and $\vec{H}$), giving diagrams of the field configurations.

b) Using the boundary conditions at the interface find the amplitude coefficients for reflection and transmission.

c) If the metal is a perfect conductor, show that in the incident medium, the fields form a system of standing waves. [2+2+1]

4. Consider a planar interface separating two uniform dielectrics of refractive indices n_1 and n_2 respectively. A plane linearly polarized EM wave of angular frequency ω is obliquely incident on the interface from medium 1.

a) Are the reflected and transmitted waves necessarily plane and linearly polarized? Explain.

b) If all the waves are p-polarized obtain the Fresnel equations for reflection and transmission.

c) Find the conditions for the reflected wave to be in phase with the incident wave.

d) Under what conditions is there no reflected wave? [1+2+1+1]

5. a) What do you mean by retardation plate?

b) Four perfect polarising plates are stacked so that the axis of each is turned 30^o clockwise with respect to the preceding plate. How much of the intensity of an incident unpolarised beam of light is transmitted by the stack?

c) Write completely the state of polarisation for the wave

$$\vec{E} = \hat{i}E_0 \cos(\omega t - kz) + \hat{j}E_0 \cos(\omega - kz + \frac{\pi}{2})$$ [1+2+2]

Group – B

6. a) Sketch clearly energy level splitting of configuration $6f\,^1 5d^1$ under (i) *L-S* (with term symbol) and (ii) *J-J*(with J value) coupling.

b) The third rotational level of $^{13}C\,^{16}O$ has been observed at 11.02011 cm^{-1} and that of second of $^{12}C\,^{16}O$ at 7.6847 cm^{-1} . Calculate the atomic weight of ^{13}C. [3+2]

7. Give the relative splitting of the various levels of an *LSJ* multiplet due to spin-orbit interaction for the ^3F, ^3D, ^4D and ^4P multiplets. Sketch the energy levels of these multiplets and indicate with arrows the allowed $^3F \rightarrow {}^3D$, $^4D \rightarrow {}^4P$ and $^4P \rightarrow {}^4S$ transitions. [5]

8. a) For a *Cu* anode with *Z=29*, calculate the approximate energies of the K_α and K_β x-rays. From the line of reasoning used to calculate the energies above, derive Moseley's law.

b) The fundamental band for DCl^{35} is centred at 2025.00 cm^{-1} . Assuming that the internuclear distance is constant at 1.288 A^o and calculate the wave numbers of the first two lines of each of *P*- and *R*-branches of DCl^{35} . [(2+1)+2]

9. Find the energies of the spectral lines emitted in the transition $3d \rightarrow 2p$ when a hydrogen atom is placed in a weak magnetic field. [5]

10.a) The vibration-rotation constants of *HCl* molecule in the three lowest vibrational levels of the ground electronic state are B_0=10.440 cm^{-1}, B_1=10.138 cm^{-1} and B_2=9.836 cm^{-1}. Calculate the equilibrium inter nuclear distance and also find the most populated rotational level at temperature of 373*K*.

b) Calculate the spin-orbit splitting of the states of hydrogen atom with *n*=30 for the largest(*l=1*) and the smallest(*l=29*) slitting? [3+2]

Paper : IX

Answer all the questions [5×10]

Group – C

11. a) Deduce the relationship of mean kinetic energy of a nucleon in a nucleus of atomic weight A.

b) Calculate the separation energy for last added, neutron in $^4He_2$ and proton in $^{16}O_8$.(Assume necessary values). [2+3]

12. a) How much minimum energy (in MeV) is required by a proton to penetrate the Coulomb potential barrier of $^{16}O_8$?

b) Find the radius of $^{49}Mn_{25}$ nucleus where the difference in Coulomb energy between the mirror nuclei $^{49}Cr_{24}$ and $^{49}Mn_{25}$ is 6.0 MeV. (Take necessary assumptions). [2+3]

13. a) Determine the stability of $^{212}Bi_{83}$ with respect to alpha, beta-plus and beta-minus decay.

b) How the existence of neutrino is justified in beta decay? [3+2]

14. The unstable isotope ^{234}Th decays by beta emission with a half life of 24.5 days-

a) What mass of ^{234}Th will produce 9.9×10^{13} decays per second ?

b) If the initial decay rate of the sample is 9.9×10^{13} decays per second. What is the decay rate after 68 days? [2+3]

15. Find the magnetic moment of $^{13}C_6$ and $^{23}Na_{11}$ nuclei. [5]

Group – D

16. a) Which of the following interaction are possible or not. Give reasons for your answers.

i) $k^+ + p \rightarrow k^+ + \Sigma^+ + k^0$

ii) $\pi^0 \rightarrow \mu^+ + e^- + \bar{\nu}_e$

iii) $n \rightarrow \pi^+ + \pi^-$

b) $k^- + p \rightarrow \Xi^- + k^+$ is allowed strong production process. Ξ^- is a strange baryon.

Find its strangeness. [3+2]

17. a) An electron is accelerated to energy 30GeV. What will be its de Broglie wavelength?

b) Ω^- is an isosinglet strange baryon. What will be its strangeness according to Gell-Mann-Nishijima scheme? [3+2]

18. a) How ancient astronomers differentiate a planet from a star?

b) What is the difference between equatorial mounting and altazimuthal mounting?

c) What do you mean by parsec (pc)? Show that 1 pc=3.09×10^{16} m.

d) One of the brightest star Sirius have apparent magnitude -1.46 and absolute magnitude 1.4. How far the star is from us? [1+2+1+1]

19. a) What do you mean by luminosity of a star?

b) Estimate the central pressure and central temperature of a star consisting of only hydrogen with mass 100 $M_\odot$ using different scaling laws. **Hint:** Use the approximate values of solar luminosity $L_\odot \approx 4 \times 10^{26}$ W and solar radius $R_\odot \approx 7 \times 10^8$ m. [1+4]

20. Describe briefly how differently a massive star evolves from a less massive star? [5]

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