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**RAJARATA UNIVERSITY OF SRI LANKA**
**FACULTY OF APPLIED SCIENCES**

B.Sc. (General) Degree in Applied Sciences
Second Year – Semester II Examination – April / May 2016

**PHY 2106 – ATOMIC & NUCLEAR PHYSICS**

Answer **All** Questions. Time allowed: $1\frac{1}{2}$ hours

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Electron Charge (e) – $1.6 \times 10^{-19}$C, $1\ C^2 = 931.5$ Mev/u

Electron Mass ($m_e$) – $9.1 \times 10^{-31}$ kg Mass of ${}^{3}_{1}H = 3.016050$ u

Reduced Plank Constant $\hbar = 1.054 \times 10^{-34}$ J.s Mass of ${}^{3}_{2}He = 3.016030$ u

Speed of Light $C = 3.0 \times 10^{8}\ ms^{-1}$

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1. Normal Zeeman effect can be observed by placing atoms inside an external magnetic field.

   a. If the energy of a photon is $\boldsymbol{E = \frac{hc}{\lambda}}$, show that the change in wavelength is given by $\boldsymbol{d\lambda = \frac{\lambda^2|dE|}{hc}}$

   b. If Cadmium atoms are placed inside a **0.009 T** magnetic field find the energy shift (***dE***) due to the Zeeman Effect.

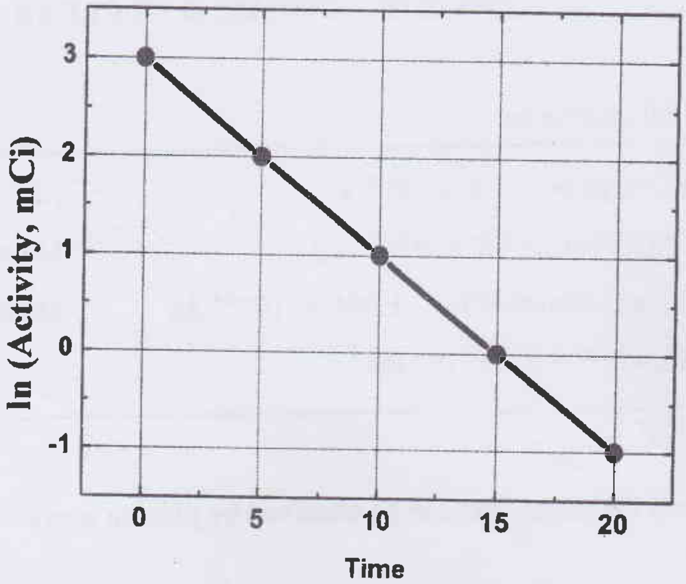
   c. Determine the normal Zeeman splitting ($\boldsymbol{d\lambda}$) of the Cadmium red line of **6438 Å** in the above magnetic field.

   d. What is the magnetic flux density B required to observe the normal Zeeman effect, if a spectrometer can resolve spectral lines separated by **0.5 Å** at **5000 Å**?

   e. In a normal Zeeman effect experiment the Calcium **4226 Å** line splits into three lines separated by **0.25 Å** in a magnetic field of **3 T**. Determine **e/m** ratio for the electron from these data.

**(35 Marks)**

2. The rapidity of decay of a particular radioactive sample is usually measured by the ***half-life.***
   a. Starting from the equation $\boldsymbol{dN = -\lambda N dt}$, Show that the half-life of a radioactive sample is given by the equation, $\boldsymbol{T_{\frac{1}{2}} = \frac{ln\,2}{\lambda}}$ ( Terms have their usual meaning)
   b. If the half-life of $^{22}$**Na** is **2.60** years, find the time required to reduce **5 mg** of $^{22}$**Na** to **1 mg**.
   c. Following is a **ln(Activity)** Vs **Time** graph of a radioactive sample of $^{55}_{24}Cr$.




   Using the above graph find the half-life of $^{55}_{24}Cr$.

   d. What is the **maximum energy** of the electron emitted in the β⁻ decay of $^{3}_{1}H$ ?

$$^{3}_{1}H \rightarrow {}^{3}_{2}He + e^{-} + \bar{\nu}$$

   e. Following equations show radioactive decay of $^{168}_{77}Ir$, $^{46}_{20}Ca$ and $^{40}_{19}K$. Identify A, B, C, D and E particles.

$$^{168}_{77}Ir \rightarrow {}^{164}_{75}Re + A$$

$$^{46}_{20}Ca \rightarrow {}^{46}_{21}Sc + B + C$$

$$^{40}_{19}K \rightarrow {}^{40}_{18}Ar + D + E$$

**(35 Marks)**

3. Consider an atomic electron in the $n = 3$ state.
   a. Write down all possible angular momentum (***l***) and magnetic (***$m_l$***) quantum numbers.

   b. Calculate the magnitude $|L|$of the orbital angular momentum and the allowed values of $L_z$ and θ.

   c. The magnetic energy of an atom placed inside an external magnetic field **B** is given by the equation $U = \mu_B B(m_l + g m_s)$, where ***g*** and ***$m_s$*** are the gyromagnetic coefficient and spin quantum number respectively. Write down all possible energies in terms of $\hbar, \boldsymbol{\omega}$ *and* $\boldsymbol{E_2}$ for ***l = 1*** level. (Assume ***g = 2***)

   d. Draw the split in ***l = 1*** level on an energy diagram.

**(30 Marks)**

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**Important Equations,**

$$\omega_L = \frac{e}{2m_e}B$$

$$E = \hbar\omega_L$$

$$|L| = \sqrt{l(l+1)}\,\hbar$$

$$L_z = m_l\hbar$$

$$A = A_0 e^{-\lambda t}$$