CHD

MNS Department
Final Examination
Spring Semester 2016
Course Title:Principles of Physics II
Course ID: PHY 112

Total Marks: 90
Times: 3 hours

Date: April 12, 2016

Instructions:

- **DO NOT** make any rough work on the question paper. Do it on the last page of your answer script.
- Answer the MCQ part in Section B, **on the question paper** and NOT in the answer script.
- **Write your name and ID#** at the top of the page of MCQ part (*i.e.* from page-3 to page-5).
- You **must return the question paper** along with your answer script.

SECTION A: Problem Solving

Answer any five questions. [5 x 16=80]

1. Four charges q, q_1, q_2 and q_3 as shown in Figure-1 are arranged so that the net force on q_1 due to other three charges is zero. Given that the charges $q_1 = +1.0\,\text{nC}$, $q_2 = +2.0\,\text{nC}$ and $q_3 = +2.0\,\text{nC}$.

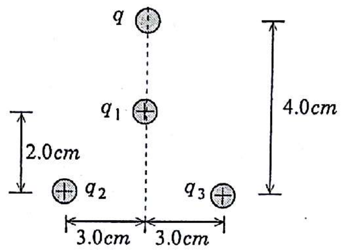

Figure 1

(a) Calculate the magnitude and polarity of charge q. 0·68 nC [8]

(b) Find the magnitude and direction of electric field at the location of charge q_1. $F_{net} = 0$ [3]

(c) Calculate the net electric potential at the location of charge q_1. 1306 V [5]

2. Figure-2 shows a closed Gaussian surface in the shape of a cube of edge length 2.00 m, with one corner at $x_1 = 5.00\,\text{m}$, and $y_1 = 4.00\,\text{m}$.The cube lies in a region where the electric field vector is given by $\vec{E} = -4.00y^2\,\hat{j} + 3.00\,\hat{k}\,\text{N/C}$ with y in meters.

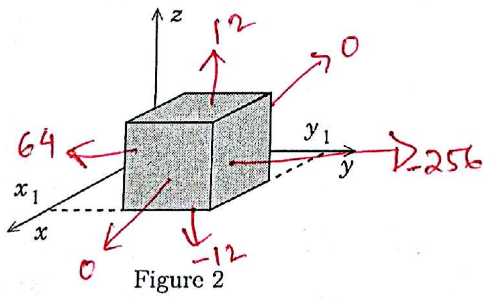

Figure 2

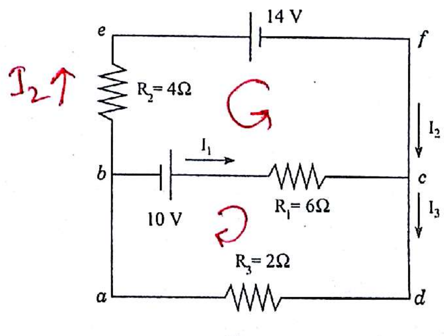

Figure 3

(a) Calculate the electric flux through each of the six faces of the cube. [12]

(b) Find the total electric charge inside the cube. -1.7×10^{-9} C [4]

3. Three resistors R_1, R_2 and R_3 are connected with two voltage sources 14 V and 10 V as shown in Figure-3. Currents I_1 and I_2 are incoming at the point c and I_3 is outgoing from c.

(a) Find out the currents I_1, I_2 and I_3 in the circuit. [9]

$I_1 = 2$, $I_2 = -3$, $I_3 = -1$

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(b) What is the potential difference between the points b and c? 2 V

(c) How much electrical power will dissipated by resistor R_3? 2W.

4. A proton is released from rest at point A, which is located next to the positive plate of a parallel plate capacitor separated by a distance $1\,m$ as shown in Figure-4. The proton then accelerates toward the negative plate and leaves the capacitor at point B through a small hole in the plate. The potential difference between the plate, $V_A - V_B$ is 2100 V. Once outside the capacitor, the proton travels at a constant velocity in a magnetic field of $\vec{B} = 0.10\,\text{T}$ which is directed out of the page. Given that the mass of the proton is 1.67×10^{-27} kg.

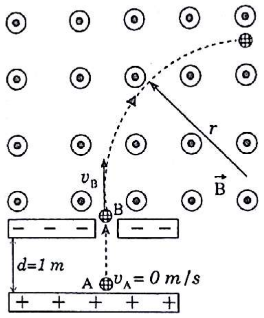

Figure 4

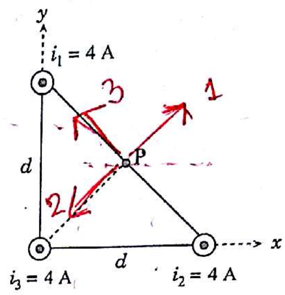

Figure 5

(a) Find the speed v_B of the proton when it leaves the negative plate of the capacitor. 6.34×10^5 m/s [5]

(b) What is magnitude of the magnetic force acting on the proton in the magnetic filed? 1.015×10^{-14} N [3]

(c) Calculate the radius r of the circular path on which the proton moves in the magnetic field. 0.066 m [5]

(d) Calculate the time periods and angular speed of the proton. 6.54×10^{-7} sec [3]

5. Three very long straight and parallel wires carry a current of 4 A each, directed out of page as shown in Figure-5. The wires pass through the vertices of a right isosceles triangle. The sides of the triangle has length $d = 2$ cm. The point P is the middle point of the hypotenuse of the triangle. You may use $\mu_o = 4\pi \times 10^{-7}$ T.m/A.

(a) Compute the magnitude of the magnetic field B_1, at point P due to the current i_1. 5.71×10^{-5} T [4]

(b) Compute the magnitude of the magnetic field B_2, at point P due to the current i_2. 5.71×10^{-5} T [4]

(c) Compute the magnitude of the magnetic field B_3, at point P due to the current i_3. 5.71×10^{-5} T [4]

(d) What are the magnitude and direction of the net magnetic field at the point P? 5.71×10^{-5} T, 135° [4]

6. A series RLC circuit has $R = 425\,\Omega$, $L = 1.25$ H and $C = 3.50$ mF. It is connected to an AC source with a frequency 60.0 Hz and $V_{max} = 150$ V.

(a) Determine the inductive reactance, capacitive reactance and impedance of the circuit. $471.24\,\Omega$, $0.76\,\Omega$, $634.02\,\Omega$ [6]

(b) Calculate I_{max} and I_{rms} current in the circuit. 0.237, 0.167 [3]

(c) What are the V_{rms} voltage readings across R and L? 71.2, 78.97 [4]

(d) Calculate the phase constant and power factor. 47.9°, 0.67 [3]

7. The isotope $^{57}_{27}$Co goes to $^{57}_{26}$Fe through an electron capture process with a half life of 272 days. The $^{57}_{27}$Co nucleus is produced in an excited state, and it almost instantaneously emits gamma rays that we can detect. Atomic mass of $^{57}_{27}$Co is $56.9362\,u$ where $1\,u = 1.66 \times 10^{-27}$ kg.

(a) Find the mean lifetime and decay constant for $^{57}_{27}$Co. 3.39×10^7 sec, $2.95 \times 10^{-8}\ s^{-1}$ [5]

(b) If the activity of a $^{57}_{27}$Co radiation source is now 2μCi how many nuclei do the source contain? 2.49×10^{12} [5]

(c) What is the mass of the $^{57}_{27}$Co source when activity is 2μCi? 2.35×10^{-13} kg [3]

(d) What will be the activity after one year? 28951.21 Bq [3]

8. (a) Calculate the wavelength and frequency of light emitted when an electron of hydrogen atom makes a transition from $n = 5$ to $n = 2$ energy states. Bohor energy level of an electron at n state is, $E_n = (-13.6\,\text{eV})\dfrac{Z^2}{n^2}$. [8]

4.35×10^{-7} m, 6.9×10^{14} Hz

(b) A pion lives for a short time before decaying into other particles. Suppose that a pion is moving at a speed of 0.990c and an observer who is stationary in a laboratory measures the pion's lifetime to be 3.5×10^{-8}s.

i. What is the lifetime according to a hypothetical person who is riding along with the pion? 4.94×10^{-9} sec [4]

ii. According to this hypothetical person, how far does the laboratory move before the pion decays? [4]

0.21 m.

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SECTION B. Multiple Choice Questions

Answer any ten questions. **10 x 1=10**

9\. i. Which of the arrangements about the magnitude of the electric fields at points A, B, and C as shown in Figure-6 is correct?

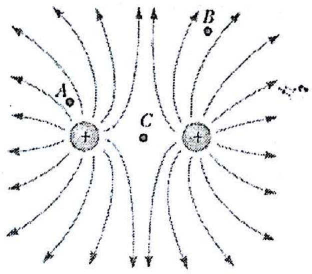
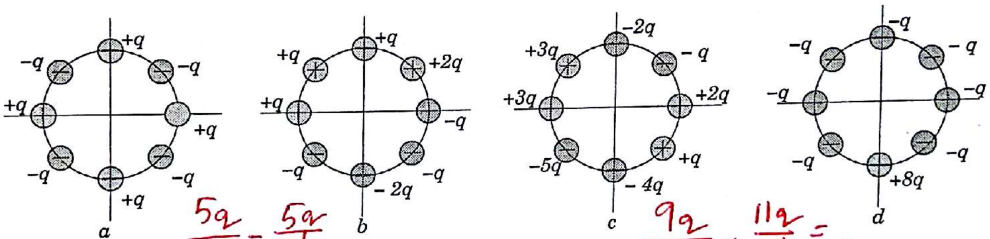


Figure 6

A. $E_A > E_B > E_C$ B. $E_C > E_B > E_A$ C. $E_A > E_C > E_B$ D. $E_A = E_B = E_C$

i. ________

ii. Four different arrangements of point charges are shown in Figure-7. In each case the charges are at the same distance from the origin. Rank the four arrangements in order of electric potential at the origin greatest first:



$\frac{4q}{d} - \frac{4q}{d} = 0$

$\frac{5q}{d} - \frac{5q}{d} = 0$

$\frac{9q}{d} - \frac{11q}{d} = -\frac{2q}{d}$

$\frac{8q}{d} - \frac{7q}{d} = \frac{q}{d}$

Figure 7

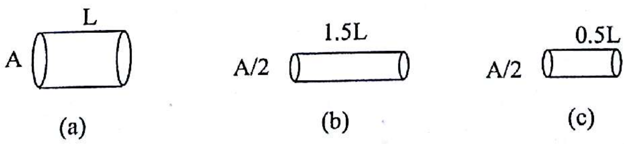
A. $a > b > c > d$ B. $b > c = a > d$ C. $c > d > b > a$ D. $d > a = b > c$

ii. ________

iii. Figure-8 shows three cylindrical copper conductors along with their face areas and lengths. A potential difference v is applied across each of their lengths. Rank them according to their current densities, greatest first:

$J = \frac{I}{A}$; $I = \frac{V}{R}$;

$R = \rho \frac{L}{A}$



$\therefore J = \frac{V}{RA} = \frac{V}{\rho L}$

Figure 8

A. $J_a > J_b > J_c$ B. $J_b = J_c > J_a$ C. $J_a = J_c > J_b$ D. $J_c > J_a > J_b$

iii. ________

iv. The time constant in an RC-circuit is given by $\tau = RC$. In a discharging RC-circuit, the charge in the capacitor after a time $t = \tau$ will be:

A. $Q_{max}(1 + e^{-1})$ B. $Q_{max}(1 + e^{1})$ C. $\frac{Q_{max}}{e}$ D. eQ_{max}

iv. ________

v. The electric field at the centre of a charged spherical hollow sphere is:

A. zero **B.** infinity **C.** same as on the surface of the sphere
D. same as on the surface of the sphere but of opposite sign

v. ____________

vi. Which of the following statements is true?

(i) At high frequency, a capacitor behaves like a conductor. → $X_C = \frac{1}{\omega_d C} = \frac{1}{2\pi f C}$
(ii) At low frequency, an inductor behaves like a conductor. → $X_L = \omega_d L$
(iii) At resonant frequency, the total impedance of an LC-circuit becomes zero.

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

A. (i)-only **B.** (ii)-only **C.** (iii)-only **D.** all of these

$X_L = X_C \Rightarrow 0$

vi. ____________

vii. Which relation regarding the magnitudes of $\oint \vec{B} \cdot d\vec{l}$ for the closed paths a through d shown in Figure-9 is true?

any answer

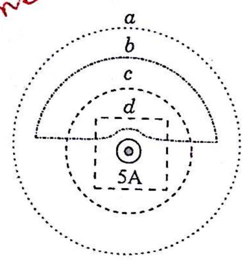


Figure 9

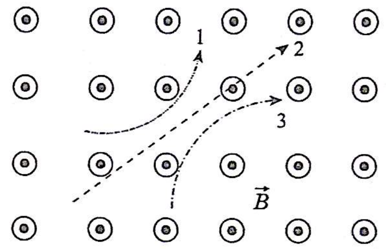


Figure 10

A. $d > c > b > a$ **B.** $b > a = c = d$ **C.** $a = b = c = d$ **D.** $a > b > c > d$

vii. ____________

viii. Three particles travel in different directions with trajectory 1, 2 and 3 through a region of space where the magnetic filed $\vec{B}$ is out of the page as shown in Figure-10. Trajectory 2 will be followed by the which of the following?

A. proton **B.** electron **C.** gamma ray **D.** none of these

viii. ____________

ix. Figure-11, shows four edge-on rectangular identical loops which carry the same current. Rank the magnitudes of the torques ($\vec{\tau} = \vec{\mu} \times \vec{B}$) acting on the rectangular loops a, b, c and d greatest first:

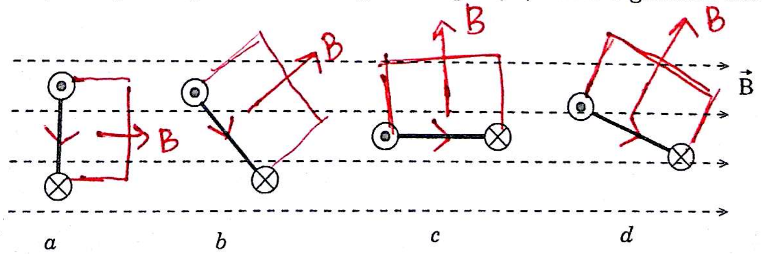


Figure 11

A. $a > b > c > d$ **B.** $a > b = d > c$ **C.** $c > d > b > a$ **D.** $d > b > a > c$

ix. ____________

x. Consider a nuclear reaction: ${}^{121}_{53}\mathrm{I} \longrightarrow {}^{121}_{52}\mathrm{Te} + (?)$. The missing particle from this reaction is:

A. ${}^{0}_{-1}e$ **B.** ${}^{0}_{0}\gamma$ **C.** ${}^{1}_{0}n$ **D.** ${}^{0}_{1}e$

x. ____________

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xi. Figure-12 shows four identical circular loops with different orientations of current I. In which situation the induced current will be clockwise?

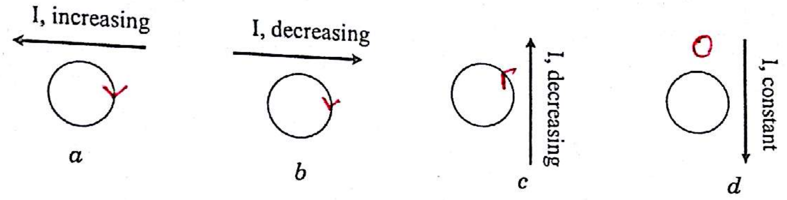


Figure 12

A. only a B. a and b C. only d D. b and c

xi. ____________

xii. Figure-13 shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitudes $\vec{B}_1$ and $\vec{B}_2$. Its path in each region is a half-circle. What is the direction of each field?

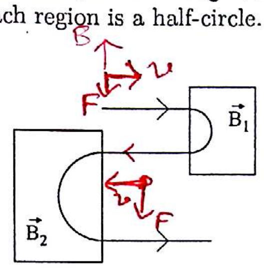


Figure 13

A. $\vec{B}_1$ is into the page and $\vec{B}_2$ is out of the page
B. $\vec{B}_1$ is out of the page and $\vec{B}_2$ is into the page
C. $\vec{B}_1$ is out of the page and $\vec{B}_2$ is out the page
D. $\vec{B}_1$ is into the page and $\vec{B}_2$ is into the page

xii. ____________

xiii. An LC-circuit is connected to an AC voltage source. The voltage drops in the inductor and the capacitor are V_L and V_C respectively. What is the phase difference between V_L and V_C?

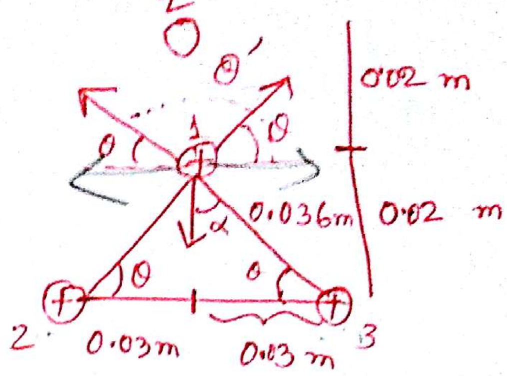
A. 0° B. 90° C. 180° D. 270°

xiii. ____________

I a) $\sqrt{0.02^2 + 0.03^2} = 0.036\ m$

$\theta = \tan^{-1}\left(\frac{0.02}{0.03}\right) = 33.7^\circ$

$\theta' = 180^\circ - 33.7^\circ = 146.3^\circ$



q will only exert a vertical force on q_1 downwards and not produce any horizontal components, so deal with vertical components only.

$F_{12} \sin 33.7^\circ + F_{13} \sin 146.3^\circ + F_{1q} \sin(-90^\circ) = 0$

$\Rightarrow \cancel{k q_1}\left(\frac{q_2}{r_1^2} \sin 33.7^\circ + \frac{q_3}{r_1^2} \sin 146.3^\circ + \frac{q}{r^2} \sin(-90^\circ)\right) = 0$

$\Rightarrow \frac{2}{(0.036)^2} \sin 33.7^\circ + \frac{2}{(0.036)^2} \sin 146.3^\circ + \frac{q}{(0.02)^2} \sin(-90^\circ) = 0$

$\Rightarrow \frac{q}{(0.02)^2} = 1712.48 \qquad \therefore q = 0.68\ nC$

b) $F_{net} = 0$ so, $E_{net} = 0$

c) $V = 9\times10^9\left(\frac{2\times10^{-9}}{0.036} + \frac{2\times10^{-9}}{0.036} + \frac{0.68\times10^{-9}}{0.02}\right)$

$= 1306\ V$

(Ans)

2 a) $\vec{E} = -4y^2\hat{j} + 3\hat{k}$

$\phi_R = (-4y^2\hat{j} + 3\hat{k}) \cdot (2^2\hat{j}) = -4 \cdot 4^2 \cdot 4 = -256 \ Nm^2/C$

$\phi_L = (-4y^2\hat{j} + 3\hat{k}) \cdot (-4\hat{j}) = 4 \cdot 2^2 \cdot 4 = 64 \ Nm^2/C$

$\phi_F = (-4y^2\hat{j} + 3\hat{k}) \cdot (2^2\hat{i}) = 0$

$\phi_{Back} = (-4y^2\hat{j} + 3\hat{k}) \cdot (-4\hat{i}) = 0$

$\phi_U = (-4y^2\hat{j} + 3\hat{k}) \cdot (4\hat{k}) = 12 \ Nm^2/C$

$\phi_{Bottom} = (-4y^2\hat{j} + 3\hat{k}) \cdot (-4\hat{k}) = -12 \ Nm^2/C$

$\phi_{net} = \frac{q_{enc}}{\varepsilon_0}$

$\Rightarrow q_{enc} = (-256 + 64) \times 8.85 \times 10^{-12}$

$= -1.7 \times 10^{-9}$

(Ans.)

——— o ———

3 a) $I_1 + I_2 - I_3 = 0$ — (i)

$14 + 4I_2 + 10 - 6I_1 = 0$

$\Rightarrow -6I_1 + 4I_2 = -24$ — (ii)

$10 - 6I_1 - 2I_3 = 0$

$\Rightarrow -6I_1 - 2I_3 = -10$ — (iii)

$I_1 = 2$ Amp $\quad I_2 = -3$ amp $\quad I_3 = -1$ amp

b) $V_b + 10 - 6I_1 = V_c$

$\Rightarrow V_b - V_c = +6 \times 2 - 10 = 2\,V$

c) $P_3 = i_3^2 R_3 = 1^2 \times 2 = 2\,W.$ (Ans.)

— o —

$\boxed{4}$ a) $\frac{1}{2} m v^2 = QV$

$\Rightarrow v = \sqrt{\frac{2QV}{m}} = \sqrt{\frac{2 \times 1.67 \times 10^{-19} \times 2100}{1.67 \times 10^{-27}}}$

$= 6.34 \times 10^{5}$ m/s

b) $F = qvB \sin 90^\circ = 1.6 \times 10^{-19} \times 6.34 \times 10^{5} \times 0.1$

$\Rightarrow F = 1.015 \times 10^{-14}$ N

c) $F = \frac{mv^2}{r}$

$\Rightarrow r = 0.066$ m

d) $v = \omega r$

$\Rightarrow \omega = 9.6 \times 10^{6}$ rad/sec

$T = \frac{2\pi}{\omega} = 6.54 \times 10^{-7}$ sec.

(Ans.)

— o —

6. a) $\omega = 2\pi f = 120\pi$

$X_L = 1.25 \times 120\pi = 471.24\,\Omega$; $[X_L = \omega_d L]$

$X_C = \dfrac{1}{3.5 \times 10^{-3} \times 120\pi} = 0.76\,\Omega$; $\left[X_C = \dfrac{1}{\omega_d C}\right]$

$\therefore Z = \sqrt{R^2 + (X_L - X_C)^2} = 634.02\,\Omega$

b) $I_{max} = \dfrac{150}{Z} = 0.237\ A$

$I_{rms} = \dfrac{0.237}{\sqrt{2}} = 0.167\ A$

c) $V_{R,max} = 0.237 \times 425 = 100.7\ V$

$V_{R,rms} = \dfrac{100.7}{\sqrt{2}} = 71.2\ V$

$V_{L,max} = 0.237 \times 471.2 = 111.67\ V$

$V_{L,rms} = \dfrac{111.67}{\sqrt{2}} = 78.97\ V$. (Ans.)

d) phase constant, $\phi = \tan^{-1} \dfrac{X_L - X_C}{R}$

$= 47.9^\circ$

power factor $= \cos\phi = 0.67$

(Ans.)

5 a) $B_1 = \frac{\mu_0 i_1}{2\pi r}(\cos 45^\circ\,\hat{i} + \sin 45^\circ\,\hat{j})$

$= \frac{4\pi \times 10^{-7} \times 4}{2\pi \times 0.014}(0.707\,\hat{i} + 0.707\,\hat{j})$

$= 4.04 \times 10^{-5}\,\hat{i} + 4.04 \times 10^{-5}\,\hat{j}$

$|B_{1,mag}| = 5.71 \times 10^{-5}$ T

b) $B_2 = \frac{\mu_0 i_2}{2\pi r}(\cos 225^\circ\,\hat{i} + \sin 225^\circ\,\hat{j})$

$= -4.04 \times 10^{-5}\,\hat{i} - 4.04 \times 10^{-5}\,\hat{j}$

$|B_{2,mag}| = 5.71 \times 10^{-5}$ T

c) $B_3 = \frac{\mu_0 i_3}{2\pi r}(\cos 135^\circ\,\hat{i} + \sin 135^\circ\,\hat{j})$

$= -4.04 \times 10^{-5}\,\hat{i} + 4.04 \times 10^{-5}\,\hat{j}$

$|B_{3,mag}| = 5.71 \times 10^{-5}$ T

d) $\vec{B}_{net} = -4.04 \times 10^{-5}\,\hat{i} + 4.04 \times 10^{-5}\,\hat{j}$

$|B_{net,mag}| = 5.71 \times 10^{-5}$ T and $\theta = 135^\circ$

(Ans.)

— o —

7 a) $t_{1/2} = 272 \text{ days} = 272 \times 24 \times 3600 \text{ sec}$

$\lambda = \frac{\ln 2}{t_{1/2}} = 2.95 \times 10^{-8} \ s^{-1}$

$\tau_{mean} = \frac{1}{\lambda} = 3.39 \times 10^{7} \ s.$

b) $R = 2 \mu Ci = 2 \times 10^{-6} \times 3.67 \times 10^{10} \ Bq = 73400 \ Bq$

$R = N\lambda \Rightarrow N = \frac{R}{\lambda} = \frac{73400}{2.95 \times 10^{-8}} = 2.49 \times 10^{12}$

c) $N = \frac{m}{amu} \Rightarrow m = N \times amu$

$= 2.49 \times 10^{12} \times 56.9362 \times 1.66 \times 10^{-27}$

$= 2.35 \times 10^{-13} \ kg$

d) $R = R_0 e^{-\lambda t}$

$\Rightarrow R = 73400 \times e^{-2.95 \times 10^{-8} \times 1 \times 365 \times 24 \times 3600}$

$= 28951.21 \ Bq.$

(Ans.)

——— 0 ———

8 a) $E = -13.606\,eV \left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

$= -13.6 \times 1.6 \times 10^{-19} \left(\frac{1}{2^2} - \frac{1}{5^2}\right) = 4.6 \times 10^{-19}$ J

$f = \frac{E}{h} = \frac{4.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 6.9 \times 10^{14}$ Hz

$\lambda = \frac{c}{f} = 4.35 \times 10^{-7}$ m. (Ans.)

b) i) $t = \frac{t_0}{\sqrt{1 - v^2/c^2}}$

$\Rightarrow t_0 = t\sqrt{1 - v^2/c^2} = 3.5 \times 10^{-8} \sqrt{1 - \left(\frac{0.99c}{c}\right)^2}$

$= 4.94 \times 10^{-9}$ sec.

ii) The actual distance covered $= v \times t$

$= 0.99c \times 4.94 \times 10^{-9}$

$L_0 = 1.47$ m.

$\therefore L = L_0 \sqrt{1 - v^2/c^2}$

$= 1.47 \sqrt{1 - (0.99)^2}$

$= 0.21$ m.

(Ans.)

———o———