CHD

BRAC UNIVERSITY

Inspiring Excellence

MNS Department

Summer Semester 2016

Final Examination

Course No: PHY 112

Course Title: Principles of Physics II

Time: 3 hours | Date: August 09, 2016

Total Marks: 90

Insturctions:

- Answer any **FIVE** questions from **Section A** and **TEN** questions from **Section B**.
- Write your **Name and #ID** in **Section B.**
- Answer **Section A** in the answer script.
- Circle the write answer in **Section B** in the question paper. **[Marks]**

1. Figure-1 shows that four particles are fixed in place and have charges $q_1 = q_2 = +5\ nC$, $q_3 = +3\ nC$, and $q_4 = -12\ nC$. Distance $d = 5.0\ \mu m$. **[4+6+6]**

   a. What is the magnitude of the net electric field at point P due to the particles? 0

   b. Calculate the magnitude and direction of electric force on an electron if it is placed at point P. 0

   c. Find the magnitude and direction of electric force on the electron at point P if the charge q_1 is removed to infinity. $2.4\times10^{-7}\,\hat{i}$ or towards q_2

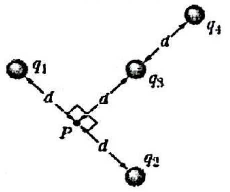

Figure-1

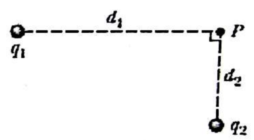

Figure-2

2. In Figure-2, the point P is at a distance of $d_1 = 4.00\ m$ from the particle 1 $(q_1 = -2e)$ and distance $d_2 = 2.00\ m$ from particle 2 $(q_2 = +2e)$, with both particles fixed in place. Given that the value of $e = 1.6\times10^{-19}\ C$. **[4+6+6]**

   a. What is the potential at the point P? $7.2\times10^{-10}\ V$

   b. How much work has to be done to bring a particle of charge $q_3 = +2e$ from infinity to the point P by the applied force and the electric field? $2.3\times10^{-28}\ J$

   c. What is the potential energy of the three-particle system? $2.56\times10^{-29}\ J$.

3. **[6+6+4]**

   a. A certain particle has a lifetime of $1.00\times10^{-7}\ sec$ when measured at rest. How far does it go before decaying if its speed is $0.99c$ when it is created?

   b. A proton and an electron, both at rest initially, combine to form a hydrogen atom in the ground state. A single photon is emitted in this process. What is its wavelength?

   c. Find out the longest and shortest wavelengths of Balmer series. Given that the value of the Rydberg constant, $R = 1.097\times10^{7}\ m^{-1}$

a)

$$t = \frac{t_0}{\sqrt{1-v^2/c^2}} = \frac{1\times10^{-7}}{\sqrt{1-(0.99)^2}} = 7.1\times10^{-7}\ sec$$

$$s = vt = 0.99\times3\times10^{8}\times7.1\times10^{-7} = 210.87\ m$$

b) $E_1 = \frac{hc}{\lambda}$

$$\Rightarrow \lambda^{-1} = \frac{-13.6\times1.6\times10^{-19}}{3\times10^{8}\times6.63\times10^{-34}}$$

$$\Rightarrow \lambda = 9.14\times10^{-8}\ m$$

c) $\frac{1}{\lambda} = 1.097\times10^{7}\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$\Rightarrow \lambda = 6.6\times10^{-7}\ m$

$\frac{1}{\lambda} = 1.097\times10^{7}\left(\frac{1}{2^2} - \frac{1}{\infty}\right)$

$\Rightarrow \lambda = 3.6\times10^{-7}\ m$

4. Figure-3 shows that $R_1 = 100\ \Omega$, $R_2 = 50\ \Omega$, and the ideal batteries have emfs $E_1 = 6.0\ V$, $E_2 = 5.0\ V$, and $E_3 = 4.0\ V$. **[8+4**

$i_1 = 0.05\ A$, $i_2 = -0.06\ A$

a. Calculate the currents in each of the batteries.

b. Calculate the voltage drop across each of the resistors. $V_1 = 5V$, $V_2 = 3V$

c. Find the potential difference between points a and b. 9V

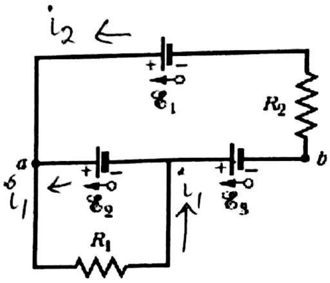

Figure-3

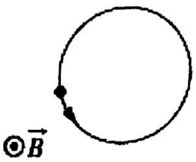

Figure-4

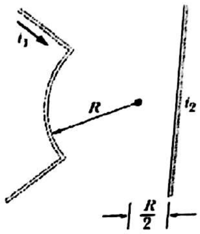

Figure-5

5. In Figure-4, a particle moves along a circle in a region of uniform magnetic field of magnitude $B = 4.00\ mT$. The particle is either a proton or an electron which experiences a magnetic force of magnitude $3.2\times10^{-15}\ N$. **[2+4+4+6]**

a. Which type of particle (proton or electron) is revolving around the circle?

b. Calculate the speed of the particle. $5\times10^{6}\ m/s$

c. Calculate the radius of the circle and also the radius if another type of particle is revolving around the circle. $r_e = 7.1\times10^{-3}\ m$, $r_p = 13.07\ m$

d. What are the frequencies of the electron and proton for their respective revolving circles?

$f_e = 1.1\times10^{8}\ Hz$, $f_p = 6\times10^{4}\ Hz$

6. Figure-5 shows, *wire-1* consists of a circular arc of radius R and two radial lengths carrying a current $i_1 = 2.0\ A$ in the direction indicated. *Wire-2* is long and straight and is carrying a current $i_2 = 3\ A$ in the upward direction and situated at a distance of $R/2$ from the centre of the arc. **[4+6+2+4]**

a. Calculate the magnitude of the magnetic field at the centre of the circular arc due to the radial lengths of *wire-1*.

b. Calculate the magnitude and direction of the magnetic field at the centre due to the circular arc if it subtends an angle of 57.3^{0}.

c. Find the magnitude and direction of magnetic field at the same point due to the straight *wire-2*.

d. Find out the current in *wire-2* if the net magnetic field at the centre becomes zero.

7. A circular loop of wire of radius $0.03\ m$ and resistance of $4.5\ \Omega$ is placed in a uniform magnetic field which is directed in through the loop. The magnetic field varies with time according to $B(t) = 4.5 + 3t$, where B is in tesla and t is in seconds. **[4+6+2+4]**

0.013 Wb a. Calculate the magnetic flux through the loop at $t = 0$ second.

3V b. Calculate the induced emf over a period of 0.15 second.

0.67 A c. What is the current in the wire during that time?

d. Calculate the self-inductance of the loop

7.4 Henry

$4.5 + 3t^2$

a) 0.013 Wb

b) 2.54×10^{-3} V

c) 5.6×10^{-4} A

d) 8160.7 Henry

8.

a. A radioactive isotope of mercury, ^{197}Hg, decays to gold, ^{197}Au, with a disintegration constant of $0.0108\ h^{-1}$. Initially there are 64×10^{19} atoms of the mercury, ^{197}Hg isotope. [10+6]

i. Calculte the half-life of the ^{197}Hg. 64.18 h = 231048 sec

ii. Calculate the initial activity of the samle. 6.9×10^{18} decay/h

iii. What fraction of the sample will remain at the end of three half-lives? 1/8

b. The binding energy of the neon isotope $_{10}Ne^{20}$ is $160.647\ MeV$. The masses of the proton and neutron are $1.007825\ u$ and $1.008665\ u$ respectively.

iv. Find the mass defect of the sample 0.17255 u / 160.647 MeV/c²

v. Find the atomic mass. 19.992 u / 1.86×10^{4} MeV/c²

Student Name:..**Student ID:**..

Section B: Multiple Choice Questions /10

9. **Each question in section B carries one mark (answer any ten):**

i. An electron traveling horizontally enters a region where a uniform electric field is directed upward. What is the direction of the force exerted on the electron once it entered the field? E

a. To the left
b. To the right
c. Upward
d. Downward

ii. The time constant of an RC circuit can be increased by

a. adding a resistor in parallel with the circuit resistance
b. adding a capacitor in parallel with the circuit capacitance
c. increasing the amplitude of the input voltage
d. exchanging the position of the resistor and capacitor in the circuit

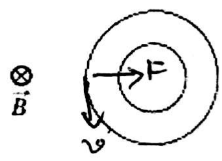

Figure-6

$\frac{mv^2}{r} = qvB$

$r = \frac{mv}{qB}$

iii. Two particles (proton and electron) travel at the same speed (Figure-6) in a uniform magnetic field along the circular paths as shown in the figure. Which particle follows the larger circle and what is its direction of its motion?

centripetal force

a. Electron and anticlockwise
b. Proton and anticlockwise
c. Electron and clockwise
d. Proton and clockwis

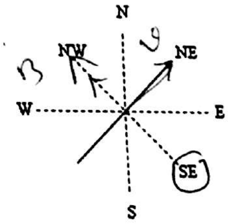

Figure-7

iv. Figure-7 shows a charged particle moving in the north east direction at right angles to a magnetic field experiences a force vertically upwards. The charged particle will not experience any force if it moves towards:

a. south west
b. north west
c. east
d. north

$F = q\vec{v}\times\vec{B}$

24 — 60×60

1 — $\frac{60\times60\times64.18}{24}$

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* North to South -> current moves

v. A coil of wire is placed in a changing magnetic field. If the number of turns in the coil is decreased, the voltage induced across the coil will

a. decrease
b. increase
c. remain constant
d. be zero

vi. Two identical coaxial circular coils carry the same current but in opposite directions. The magnitude of the magnetic field at a point on the axis midway between the coil is

Coaxial - common axis

a. zero
b. the same as that produced by one coil
c. twice that produced by one coil
d. half that produced by one coil

vii. Direction of induced current always:

a. opposes the cause creating the current
b. remains the same as that of the cause creating the current
c. equal to the cause creating the current
d. none of these

viii. Two thin parallel wires are carrying currents along the same direction. The force experienced by one due to the other is

b. parallel to the lines
b. perpendicular to the lines and is attractive
c. perpendicular to the lines and is repulsive
c. zero

ix. Beta particles from various radioactive sources all have:

c. the same mass
b. the same speed
c. the same charge
d. the same energy in magnetic field

x. What type of magnetic material repel external magnetic field?

d. diamagnetic
b. paramagnetic.
c. ferromagnetic
d. none of these

xi. Ultraviolet electromagnetic waves fall in:

a. Lyman Series
b. Balmer Series
c. Paschen Series
d. Pfund Series

xii. According to Bohr's atomic model the angular momentum of the electron in the n^{th} orbit is equal to:

a. $h/2\pi$
b. $2\pi/h$
c. $nh/2\pi$
d. nh/π

a) $$E_1 = \frac{9\times10^{9} \times 5\times10^{-9}}{(5\times10^{-6})^2}\left(\cos 180^\circ \hat{i} + \sin 180^\circ \hat{j}\right)$$

$$= -1.8\times10^{12}\,\hat{i}$$

$$E_2 = \frac{9\times10^{9}\times5\times10^{-9}}{(5\times10^{-6})^2}\left(\cos 0^\circ \hat{i} + \sin 0^\circ \hat{j}\right) = 1.8\times10^{12}\,\hat{i}$$

$$E_3 = \frac{9\times10^{9}\times3\times10^{-9}}{(5\times10^{-6})^2}\left(\cos 270^\circ \hat{i} + \sin 270^\circ \hat{j}\right) = -1.8\times10^{12}\,\hat{j}$$

$$E_4 = \frac{9\times10^{9}\times 12\times10^{-9}}{(2\times5\times10^{-6})^2}\left(\cos 90^\circ \hat{i} + \sin 90^\circ \hat{j}\right) = 1.8\times10^{12}\,\hat{j}$$

$\therefore\ E_{net} = 0$

b) $$F_{net} = E_{net}\times q = 0$$

c) $$F_{25} = E_2\times q = 1.8\times10^{12}\,\hat{i}\times1.6\times10^{-19} = 2.4\times10^{-7}\,\hat{i}$$

$$F_{35} = -2.4\times10^{12}\,\hat{j}$$

$$F_{45} = +2.4\times10^{12}\,\hat{j}$$

$\therefore\ F_{net} = 2.4\times10^{-7}\,\hat{i}$

if q_1 is removed to infinity.

(Ans.)

—— o ——

$\boxed{3}$ a) $$t = \frac{t_0}{\sqrt{1 - v^2/c^2}} = \frac{1 \times 10^{-7}}{\sqrt{1 - (0.99)^2}} = 7.1 \times 10^{-7} \text{ sec}$$

$$S = vt = 0.99 \times 3 \times 10^{8} \times 7.1 \times 10^{-7} = 210.87 \text{ m.}$$

b) $$E = \frac{hc}{\lambda}$$; [at ground state $n=1$]

$$\Rightarrow \lambda = \frac{hc}{E_1} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{+13.6 \times 1.6 \times 10^{-19}} = 9.14 \times 10^{-8} \text{ m.}$$

c) $$\frac{1}{\lambda} = 1.097 \times 10^{7} \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\therefore \lambda = 6.6 \times 10^{-7} \text{ m}$$

8]
3]
5]

$$\frac{1}{\lambda} = 1.097 \times 10^{7} \left(\frac{1}{2^2} - \frac{1}{\alpha}\right)$$

$$\therefore \lambda = 3.6 \times 10^{-7} \text{ m.}$$

(Ans.)

— o —

$\boxed{2}$ a) $V_p = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{d_1} + \frac{q_2}{d_2}\right)$

$= 9\times10^{9}\left(\frac{-2\times1.6\times10^{-19}}{4} + \frac{2\times1.6\times10^{-19}}{2}\right)$

$= 7.2\times10^{-10}\ V.$

b) $W = -q_3\left(V_\infty - V_p\right)$

$= -2\times1.6\times10^{-19}\left(0 - 7.2\times10^{-10}\right)$

$= 2.3\times10^{-28}\ J$

c) $U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{\sqrt{d_1^2+d_2^2}} + \frac{q_1 q_3}{d_1} + \frac{q_2 q_3}{d_2}\right)$

$= 9\times10^{9}\left(\frac{-2\times2\times1.6\times10^{-19}\times1.6\times10^{-19}}{4.5} - \frac{2\times2\times1.6\times10^{-19}\times1.6\times10^{-19}}{4}\right.$

$\left. + \frac{2\times2\times1.6\times10^{-19}\times1.6\times10^{-19}}{2}\right)$

$= 2.56\times10^{-29}\ J.$

— o —

$\boxed{4}$ a) $\varepsilon_2 - i_1 R_1 = 0$

$$\Rightarrow i_1 = \frac{\varepsilon_2}{R_1} = \frac{5}{100\,\Omega} = 0.05\,A$$

$$\varepsilon_1 - \varepsilon_2 - \varepsilon_3 - i_2 R_2 = 0$$

$$\Rightarrow i_2 = \frac{6-5-4}{50} = -0.06\,A$$

b) $V_2 = i_2 R_2 = 0.06 \times 50 = 3\,V$

$V_1 = i_1 R_1 = 0.05 \times 100 = 5\,V$

c) $V_a - \varepsilon_2 - \varepsilon_3 = V_b$

$\Rightarrow V_a - V_b = \varepsilon_2 + \varepsilon_3 = 5 + 4 = 9\,V.$

(Ans.)

——— o ———

$\boxed{7}$ $B(t) = 4.5 + 3t$

a) $\phi = BA = 0.013$ Wb

b) $\varepsilon = \frac{d\phi}{dt} = \frac{d}{dt}(4.5 + 3t)$

$= 3$ V

c) $i = \frac{\varepsilon}{R} = 0.67$ amp

d) $Li = N\phi$ $\quad \phi = 4.5 + (3 \times 0.15)$

$\Rightarrow L = \frac{4.95}{0.67} = \cancel{\ldots}\ 7.4\,H$

$B(t) = 4.5 + 3t^2$

a) $\phi = BA = 0.013$ Wb

b) $\varepsilon = \frac{d\phi}{dt} = \frac{d}{dt}(BA)$

$= 2 \times 3 \times \pi \times (0.03)^2$

$= 2.54 \times 10^{-3}$ V

c) $i = \frac{\varepsilon}{R} = 5.6 \times 10^{-4}$ Amp

d) $L = \frac{\phi}{i} = 8160.7$ Henry

(Ans.)

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5 a) electron

b) $F = qvB$

$\Rightarrow 3.2 \times 10^{-15} = 1.6 \times 10^{-19} \times v \times 4 \times 10^{-3}$

$\Rightarrow v = 5 \times 10^{6}$ m/s

c) $\dfrac{mv^2}{r} = qvB$

$\Rightarrow r = \dfrac{mv}{qB}$

$\therefore r_{electron} = \dfrac{9.1 \times 10^{-31} \times 5 \times 10^{6}}{1.6 \times 10^{-19} \times 4 \times 10^{-3}} = 7.1 \times 10^{-3}$ m

[8]

$r_{proton} = \dfrac{1.673 \times 10^{-27} \times 5 \times 10^{+6}}{1.6 \times 10^{-19} \times 4 \times 10^{-3}} = \cancel{1.3 \times 10^{-11}\text{ m}}$. [3]

[5]

13.07 m

d) $T = \dfrac{2\pi r}{v}$

$\Rightarrow \dfrac{1}{f} = \dfrac{2\pi r}{v}$ $\therefore f = \dfrac{v}{2\pi r}$

$f_{electron} = \dfrac{5 \times 10^{6}}{2 \times \pi \times 7.1 \times 10^{-15}} = 1.1 \times 10^{8}$ Hz

$f_{proton} = \dfrac{5 \times 10^{6}}{2 \times \pi \times 1.3 \times 10^{-11}} = 6.0 \times 10^{4}$ Hz

(Ans.)

$\boxed{8}$ 1) a) $\lambda = 0.0108\ h^{-1}$ = 38.88 sec^{-1}

$\therefore t_{1/2} = \frac{\ln 2}{0.0108} = 64.18\ h$ = 231048 sec

b) $R_0 = N_0 \lambda = 64 \times 10^{19} \times 0.0108 = 6.9 \times 10^{18}$ decay/h

$= \cancel{64 \times 10^{19} \times 0.62 = 4 \times 10^{20}\ Bq}$

c) $N = N_0 e^{-\lambda t}$

$t = 64.18\ h \times 3 = 192.54\ h$

$= 64 \times 10^{19}\ e^{-0.0108 \times 192.54}$

$= 8 \times 10^{19}$

Fraction $= \frac{8 \times 10^{19}}{64 \times 10^{19}} = \frac{1}{8}$

—— 0 ——

b) iv) $E = \Delta m c^2$

$\Rightarrow 160.647\ MeV = \Delta m c^2$

$\Rightarrow \Delta m = 160.647\ MeV/c^2$

$= 0.17255\ u$

v) $\Delta m = 10 \times 1.007825 + 10 \times 1.008665$ − atomic mass

$\Rightarrow$ atomic mass $= 19.992\ u$

$= 1.86 \times 10^4\ MeV/c^2$

—— 0 ——

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6 a) $B = \frac{\mu_0 i \phi}{4\pi R} + \frac{\mu_0 i}{2\pi R} - \frac{\mu_0 i}{2\pi R}$ $\quad 1^\circ = 0.0174$ rad

=80]

b) $B = \frac{\mu_0 i \phi}{4\pi R}$

$\boxed{7}$ $B(t) = 4.5 + \cancel{3}\,3t$

a) $\phi = BA$

$= 4.5 \times \pi (0.03)^2$

$= 0.013$ ~~Tesla~~ Wb

b) $\varepsilon = \frac{d\phi}{dt} = \frac{d}{dt}(4.5 + 3t)$

$= 3\,V$

$= \cancel{\frac{0.013}{0.15}}$

$= \cancel{0.086\,V}$

c) $i = \frac{\varepsilon}{R} = \frac{3}{4.5} = 0.67\,A$

$= \cancel{\frac{0.086}{4.5}}$

$= \cancel{0.019\,A}$

d) $Li = N\phi$

$\Rightarrow L = \frac{\phi}{i} = \frac{0.013}{0.67}$

$= 0.02\,H$

$= \cancel{0.68}$ ~~Henry~~

(Ans.)

$B(t) = 4.5 + 3t^2$

a) $\phi = BA$

$= 0.013\,Wb$

b) $\pi r^2 = 2.83 \times 10^{-3}$

$\phi = BA$

$= 8.49 \times 10^{-7}$

$\therefore \varepsilon = \frac{d\phi}{dt}$

$\therefore \varepsilon(0.15) = 2 \times 3 \times \pi \times (0.03)^2 \times 0.15$

$= 2.54 \times 10^{-3}\,V$

c) $i = \frac{\varepsilon}{R}$

$= 5.6 \times 10^{-4}$ Amp

d) $L = \frac{\phi}{i}$

$= \frac{4.57}{5.6 \times 10^{-4}}$

$= 8160.7\,H$

(Ans)