BRAC UNIVERSITY
Inspiring Excellence

CHD

# MNS Department
## Fall Semester 2015
## Final Examination
## Course No: PHY 112
## Course Title: Principles of Physics II

Time: 3 hours
Total Marks: 90

Date: December10, 2015

**Insturctions:**

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

**[Marks]**

1. In Figure-1, the four particles are fixed in place and have charges$q_1 = q_2 = +5e$, $q_3 = +3e$ and $q_4 = -12e$. Distance $d = 5.0\ \mu m$. **[5+5+4+2]**
   a. What is the net electric field at point P due to the particles?
   b. Calculate the net electric field at point P if the charge $q_3$ is rotated by an angle of $180^0$ about the point P on the same plane.
   c. Calculate the net force on an α-particle placed at point P for part b. (You should find out the charge of α-particle)
   d. How does the net field change if charges $q_1$ and $q_2$ interchange their positions?

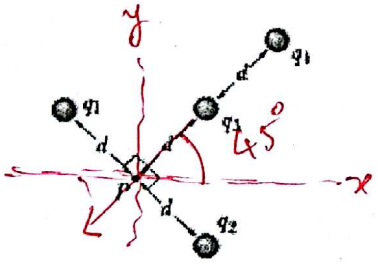


Figure-1

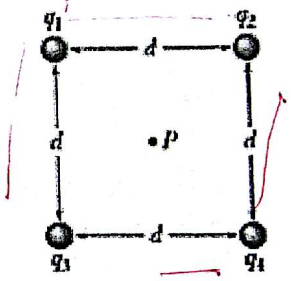


Figure-2

2. In Figure-2, four point charges are placed at the corners of a square. The distance $d = 1.3\ m$ and the charges are $q_1 = +12\ nC$, $q_2 = +31\ nC$, $q_3 = -24\ nC$ and $q_4 = +17\ nC$. **[4+6+4+2]**
   a. Calculate the electrical potential at point P due to the point charges.
   b. What is the potential energy of the system?
   c. Calculate the amount of work done to remove charge $q_3$ from the square to infinity.
   d. Calculate the change in electric potential at point P if charges rotate clockwise to the next.

3. In an RC circuit, a $1.40\ M\Omega$ resistor and a $1.80\ \mu F$ capacitor are connected is series with a battery of emf$12.0\ V$. **[3+2+6+5]**
   a. Find the maximum charge that will appear on the capacitor during charging.
   b. Calculate the time constant of the RC circuit.
   c. Calculate the amount of stored charge in the discharging process of a capacitor after one time constant.
   d. How long does the capacitor take to develop a potential difference of half of its maximum value?

4. In Figure-3, the resistances are $R_1 = 1\Omega$ and $R_2 = 2\Omega$ and the ideal batteries have emfs $E_1 = 2V$ and $E_2 = E_3 = 4V$. **[9+4+3]**
   a. What are the magnitudes and directions of the currents in batteries 1, 2 and 3?
   b. What is the potential difference $V_a - V_b$?
   c. What is the power dissipation across $R_2$?

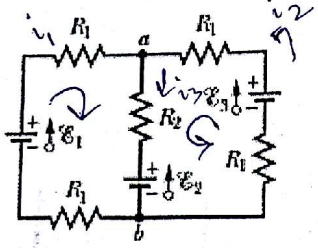

Figure-3

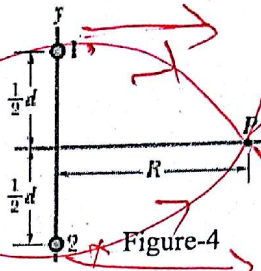

Figure-4

5. In Figure-4, two long parallel wires are directed along the *z-axis* and separated by a distance of $d = 18.6\ cm$. Each wire carries a current of $4.23\ A$ out of the page in wire 1 and into the page in wire 2. **[6+4+6]**
   a. Calculate the magnitude and direction of magnetic fields at the positions of each of the wires due to currents.
   b. Find the magnitude and direction of the magnetic force per unit lengths on each of the wires.
   c. What is the net magnetic field in unit-vector notation at point P at distance $R = 34.2\ cm$ due to the two currents?

6. A circular coil has a $10.0\ cm$ radius and consists of $30.0$ closely wound turns of wire. An externally produced magnetic field of magnitude $2.60\ mT$ is perpendicular to the coil. **[4+6+6]**
   a) If no current is in the coil, what magnetic flux links its turns?
   b) When the current in the coil is $3.80\ A$ in a certain direction, the net flux through the coil is found to vanish. What is the inductance of the coil?
   c) Calculate the magnitude of the average induced emf if the coil takes $15\ ms$ to increase the current up to $3.80\ A$.

7. A photon incident on a hydrogen atom causes the electron to make a transition from $n = 1$ orbital to the $n = 3$ orbital. **[6+6+4]**
   a. Find out the energy of the incident photon.
   b. What are the wavelength and frequency of the incident photon?
   c. Calculate the radii of the orbits mentioned above.

8. **[6+4+6]**
   a. A dose of $8.60\ \mu Ci$ of a radioactive isotope is injected into a patient. The isotope has a half-life of $3.0\ h$. How many of the isotope parents are injected?( $1Ci = 3.7\times10^{10}Bq$ & $1Bq = 1\ decay/sec$)

   b. An observer on a spacecraft moving at $0.700c$ relative to the earth finds that a car takes $40.0\ min$ to make a trip. How long does the trip take as observed by the driver of the car?

   c. The binding energy of ${}_{12}Mg^{24}$ is $198.25\ MeV$. Find its atomic mass. Given that the mass of the proton and the neutron are $1.007825\ u$ and $1.008665\ u$ respectively.

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## Section B: Multiple Choice Questions ____/ 10

**Each question in Section B carries one mark:**

1. Kirchhoff's second law is based on law of conservation of:
   a) Charge
   b) Energy
   c) Momentum
   d) Mass

2. To increase the current in a series RL circuit, the frequency:
   a) should be increased
   b) should be decreased
   c) should be constant
   d) cannot be determined without values

3. A metallic ring is attached to the wall of the room when the north pole of magnet is brought near the ring then the induced current in the ring:
   a) is zero
   b) moves clockwise
   c) moves anticlockwise
   d) is infinite

4. The permanent magnets are made from which of following materials ?
   a) soft iron
   b) ferromagnetic materials
   c) paramagnetic materials
   d) diamagnetic materials

5. The field at any point on the axis of a current carrying coil will be
   a) parallel to the axis
   b) perpendicular to the axis
   c) at angle of $45^0$ with the axis
   d) zero.

6. Special theory of relativity treats problems involving:
   a) inertial frames of reference
   b) non-inertial frames of reference
   c) non-accelerating frame of reference
   d) accelerating frames of reference

7. An electric field line and an equipotential surface are
   a) always at $90°$ to each other.
   b) always parallel
   c) inclined at any angle
   d) none of these

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8. Which field is associated with the capacitor?
   a) magnetic
   b) electric
   c) both a and b
   d) none of these

9. The magnetic field lines inside a long, current carrying solenoid are nearly:
   a) straight
   b) circular
   c) parabolic
   d) elliptical

10. In the direction of electric field, the electric potential will:
   a) decrease
   b) increase
   c) become zero
   d) remain unchanged

11. Most of the energy produced by the sun is due to:
   a) nuclear fission
   b) nuclear fusion
   c) chemical reaction
   d) gravitational collapse

12. Beta particles from various radioactive sources all have:
   a) the same mass
   b) the same speed
   c) the same charge
   d) the same energy in magnetic field

13. A point charge is placed at the centre of a spherical Gaussian surface. The electric flux $\phi_E$ is changed if

   a) the sphere is replaced by a cube of the same volume
   b) the sphere is replaced by a cube of one-tenth the volume
   c) the point charge is moved off centre (but still inside the original sphere)
   d) the point charge is moved to just outside the sphere

1 a) $E_3 = \frac{1}{4\pi\epsilon_0} \frac{3e}{(5\times10^{-6})^2} \left[\cos(180+45^\circ)\hat{i} + \sin(180+45^\circ)\hat{j}\right]$

$= 172.8\ [-0.707\,\hat{i} - 0.707\,\hat{j}]$

$E_4 = \frac{1}{4\pi\epsilon_0} \frac{12e}{(2\times5\times10^{-6})^2} \left[\cos 45^\circ\,\hat{i} + \sin 45^\circ\,\hat{j}\right]$

$= 172.8\ [0.707\,\hat{i} + 0.707\,\hat{j}]$

$E_1$ and $E_2$ are of same magnitude and cancel each other because of opposite direction.

$\therefore E_{net} = 0$

b) $E_3 = 9\times10^9 \frac{3e}{(5\times10^{-6})^2} \left[\cos 45^\circ\,\hat{i} + \sin 45^\circ\,\hat{j}\right]$

$= 172.8\ [0.707\,\hat{i} + 0.707\,\hat{j}]$

$E_4 = 172.8\ \left[\cos 45^\circ\,\hat{i} + \sin 45^\circ\,\hat{j}\right] = 172.8\ [0.707\,\hat{i} + 0.707\,\hat{j}]$

$\therefore E_{net} = 244.34\,\hat{i} + 244.34\,\hat{j}$

c) $\alpha = +2e$.

$\therefore F = q E_{net}$

$= 2\times1.6\times10^{-19}\ [244.34\,\hat{i} + 244.34\,\hat{j}]$

$= 7.82\times10^{-17}\,\hat{i} + 7.82\times10^{-17}\,\hat{j}$

d) No change.

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2 a) $V_p = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1}{r} + \frac{q_2}{r} - \frac{q_3}{r} + \frac{q_4}{r}\right]$ $\quad [r = 0.919\ m]$

$= 9\times10^9 \left(\frac{12 + 31 - 24 + 17}{0.919}\right)\times10^{-9}$

$= 352.55\ V$

b) $U = 9\times10^9\left[\frac{q_1q_2}{1.3} + \frac{q_1q_3}{1.3} + \frac{q_1q_4}{1.84} + \frac{q_2q_4}{1.3} + \frac{q_2q_3}{1.84} + \frac{q_3q_4}{1.3}\right]$

$= 9\times10^9\left[\frac{12\times10^{-9}\times31\times10^{-9}}{1.3} - \frac{12\times10^{-9}\times24\times10^{-9}}{1.3} + \frac{12\times10^{-9}\times17\times10^{-9}}{1.84}\right.$

$\left. + \frac{31\times10^{-9}\times17\times10^{-9}}{1.3} - \frac{31\times10^{-9}\times24\times10^{-9}}{1.84} - \frac{24\times10^{-9}\times17\times10^{-9}}{1.3}\right]$

$= 9\times10^9\left[2.86\times10^{-16} - 2.22\times10^{-16} + 1.11\times10^{-16} + 4.05\times10^{-6}\right.$

$\left. - 4.04\times10^{-16} - 3.14\times10^{-16}\right]$

$= -1.242\times10^{-6}$ J.

c) $W = -q\Delta V = -(-24\times10^{-9})\left(0 - \frac{1}{4\pi\varepsilon_0}\frac{(-24\times10^{-9})}{0.919}\right)$

$= 5.64\times10^{-6}$ J.

d) No change.

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[3] a) $Q_{max} = C\mathcal{E}$

$= 1.8\times10^{-6}\times12$

$= 2.16\times10^{-5}$ C

b) $\tau = RC$

$= 1.4\times10^6\times1.8\times10^{-6}$

$= 2.52$ sec

c) $Q = Q_0 e^{-t/RC}$

$= Q_0 e^{-1}$

$= 2.16\times10^{-5}\times0.37$

$= 8\times10^{-6}$ C

d) $V_c = V_s\left(1 - e^{-t/RC}\right)$

$\Rightarrow \frac{V_s}{2} = V_s\left(1 - e^{-t/RC}\right)$

$\Rightarrow e^{-t/RC} = \frac{1}{2}$

$\Rightarrow t = 1.746$ sec.

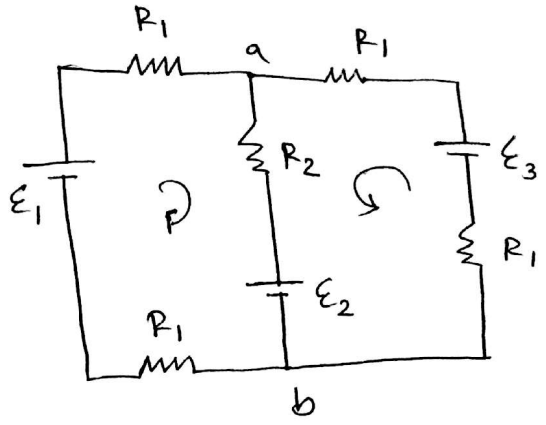
$V_s$ = Source voltage
$V_c$ = voltage across capacitor

[4] a) $R_1 = 1\,\Omega$

$R_2 = 2\,\Omega$

$E_1 = 2V$

$E_2 = 4V$ , $E_3 = 4V$




$i_1 = i_2 + i_3$

$\varepsilon_1 - i_1 R_1 - i_3 R_2 - \varepsilon_2 - i_1 R_1 = 0$

$\Rightarrow 2 - i_1 - 2i_3 - 4 - i_1 = 0$

$\Rightarrow -2i_1 - 2i_3 - 2 = 0$

$\varepsilon_3 + i_2 R_1 - i_3 R_2 - \varepsilon_2 + i_2 R_1 = 0$

$\Rightarrow 4 - i_2 - 2i_3 - 4 - i_2 = 0$

$\Rightarrow 2i_2 - 2i_3 = 0$

$i_1 = \frac{2}{3}$

$= 0.67\,A$

$i_2 = \frac{1}{3}$

$= 0.33\,A$

$i_3 = \frac{1}{3}$

$= 0.33\,A$

b)

c) $P = i_3^2 R_2 = 0.22\,W$.

— o —

5 a) $B_2 = \frac{\mu_0 i_1}{2\pi d} = \frac{4\pi \times 10^{-7} \times 4.23}{2\pi \times \left(\frac{18.6}{100}\right)}$

$= 4.55 \times 10^{-6}$ T

(towards $+x$)

$B_1 = \frac{\mu_0 i_2}{2\pi d} = 4.55 \times 10^{-6}$ T (towards $+x$)

b) $\frac{F}{L} = \frac{\mu_0 i_1 i_2}{2\pi d} = \frac{4\pi \times 10^{-7} \times 4.23 \times 4.23}{2\pi \times \left(\frac{18.6}{100}\right)}$

$= 1.92 \times 10^{-5}$ N

c) distance $= \sqrt{(34.2)^2 + (9.3)^2} = 35.44$ cm

$B_1 = \frac{\mu_0 i_2 \cos(15.21^\circ)\, \hat{i}}{2\pi r}$

$= \frac{4\pi \times 10^{-7} \times 4.23 \times 0.96\, \hat{i}}{2\pi \times \frac{35.44}{100}} = 2.29 \times 10^{-6}\, \hat{i}$

$B_2 = \frac{\mu_0 i_1}{2\pi r} \cos(-15.21^\circ)\, \hat{i} = 2.29 \times 10^{-6}\, \hat{i}$

$\therefore B_{net} = 4.58 \times 10^{-6}\, \hat{i}$ (Ans.)

[6] a) $\phi_{turns} = N\phi_B = NBA = NB(\pi r^2)$

$= 30 \times (2.6 \times 10^{-3}) \times \pi \times \left(\frac{10}{100}\right)^2$

$= 2.45 \times 10^{-3}$ Wb

b) $L = \frac{N\phi_B}{i} = \frac{2.45 \times 10^{-3}}{3.8} = 6.45 \times 10^{-4}$ H

c) $\varepsilon = -L\frac{\Delta i}{\Delta t} = -6.45 \times 10^{-4} \quad \frac{3.8}{15 \times 10^{-3}}$

$= -0.16$ V. (Ans.)

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[7] a) $E = -13.606\left(\frac{1}{1^2} - \frac{1}{9}\right)$ eV

$= -12.09$ eV $= 1.94 \times 10^{-18}$ J

b) $E = hf \Rightarrow f = \frac{E}{h} = \frac{1.94 \times 10^{-18}}{6.63 \times 10^{-34}}$

$= 2.93 \times 10^{15}$ Hz

$\frac{12.09}{6.63 \times 10^{-34}}$

$= 1.82 \times 10^{34}$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.93 \times 10^{15}} = 1.02 \times 10^{-7}$ m

$1.65 \times 10^{-26}$ m

c) $r_1 = a_0 n^2 = 0.529$ nm $= 5.29 \times 10^{-10}$ m.

$r_3 = a_0 3^2 = 0.529 \times 10^{-9} \times 9 = 4.76 \times 10^{-9}$ m.

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[8] a) $R_0 = 8.6\ \mu Ci = 8.6 \times 10^{-6} \times 3.7 \times 10^{10}\ Bq$

$= 318200\ Bq.$

$t_{1/2} = 3h = 3 \times 60 \times 60 = 10800$

$\lambda = \frac{\ln 2}{t_{1/2}} = 6.42 \times 10^{-5}$

$\therefore R_0 = \lambda N_0 \Rightarrow N_0 = 4.9 \times 10^{9}$

b) $v = 0.7c$ , $t = 40\ min$

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

$= 40\sqrt{1 - (0.7)^2}$

$= 28.57\ min$

c) 12 protons, 12 neutrons.

$\therefore BE = [(12 \times 1.007825) + (12 \times 1.008665) - Mg]\, c^2$

$\Rightarrow 198.25\ MeV = [24.19788 - Mg]\, 931.5\ MeV/u$

$\Rightarrow 0.2128\ u = 24.19788 - Mg$

$\Rightarrow Mg = 23.985\ u.$ (Ans.)

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