(5)

CHD

BRAC University
MNS Department
Final Examination
Spring Semester 2014
Course Title: Principles of Physics - II
Course ID: PHY 112

Total Marks: 90
Times: 3 hours

Date: April 24, 2014

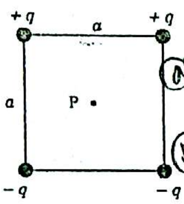
Instructions: Read them carefully:

- **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**, NOT on the answer script.
- Write your **name and ID#** at the top of each page of the 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. Marks are as indicated:

1. Four point charges are placed at each corner of a square with side length $a = 1.50\,m$. The charges all have the same magnitude $q = 20.0\mu C$. Two of the charges are positive and two are negative, as shown in Figure-1.



(a) $\vec{E} = 4.5\times10^5$ N/C
(b) $\vec{F} = 6.75$ N
(c) $\vec{a} = 3.8\times10^8$ m/s²

Figure 1: Question-1

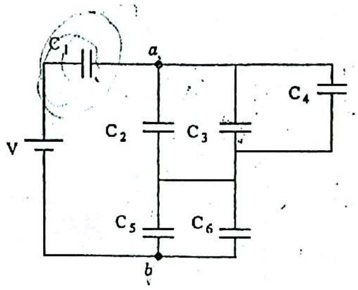


Figure 2: Question-2(b)

(a) (7 marks) What is the direction and magnitude of the net electric field at the centre of the square due to the four charges?

(b) (5 marks) If a particle of charge $q_o = -15.0\mu C$ and mass $m = 1.78 \times 10^{-8}\,kg$ is placed at the centre P of the square, calculate the net force on this charge due to the other charges.

(c) (4 marks) If the charged particle q_o is released from rest at point P, find the magnitude and direction of its acceleration just after being released.

2. (a) The plates of a parallel-plate capacitor in vacuum are $5.00\,mm$ apart and the area of each plate is $2.00\,m^2$. A $10.0\,kV$ potential difference is applied across the capacitor.
   i. (6 marks) Compute the capacitance C and the charge Q on each plate.
   ii. (4 marks) Calculate the magnitude of the electric field between the plates.

(b) (6 marks) Figure-2 shows a system of six capacitors with capacitance $C_1 = C_5 = C_6 = 6\mu$F and $C_2 = C_3 = C_4 = 4\mu$F. The potential difference across the points a and b is V_{ab}. Calculate the equivalent capacitance C_{ab} between the points a and b.

(a) $C = 3.5\times10^{-9}$ F
$Q = 3.5\times10^{-5}$ C
$E = 9.9\times10^{7}$ N/C
$6 = 1.77\times10^{-5}$
(b) 6μF

3. A particle with a charge $q = -1.24 \times 10^{-8}$ C and mass $m = 1.81 \times 10^{-3}\,kg$ is moving with a velocity $\vec{v} = (4.19 \times 10^4\,m/s)\hat{\imath} - (3.85 \times 10^4\,m/s)\hat{\jmath}$ in a uniform magnetic field $\vec{B} = (1.40\,\hat{\imath})$T.

(a) (7 marks) Compute the magnetic force $\vec{F}$ experienced by the charged particle.

(b) (5 marks) Find the magnitude and direction of the acceleration of the charged particle.

(c) (4 marks) What is the angle between $\vec{B}$ and $\vec{F}$?

(a) $\vec{F} = -6.68\times10^{-4}$
$\vec{a} = 3.69\times10^{-1}$
(c) 90°

Name: ______________________________ ID#: ____________________

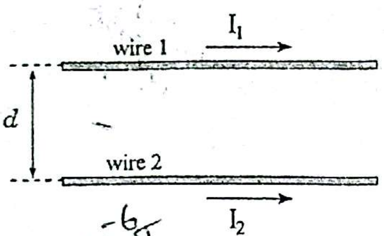


Figure 3: Question-4

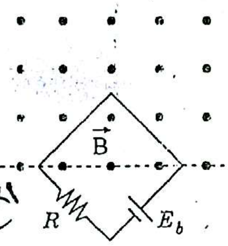


Figure 4: Question-5

$B_1 = \frac{\mu_0 I}{\pi d}$

(i) $= \frac{4\pi\times10^{-7}\times2.5}{\pi\times.22} = 4.55\times10^{-6}$ T

$B_2 = 1\times10^{-5}$

(b) $F_{12} = \frac{\mu_0 L I_1 I_2}{2\pi d} = \frac{4\pi\times10^{-7}\times2.5\times5.5\times1}{2\pi\times.22} = 1.25\times10^{-5}$ N

4. Two infinitely long wires separated by a distance $d = 22\,cm$ are carrying currents in the same direction as shown in Figure-3. Current in wire 1 is $I_1 = 2.5$ A and current in the wire 2 is $I_2 = 5.5$ A.

   (a) (7 marks) Find the magnitude and direction of the net magnetic field $\vec{B}$ half-way between the wires.

   (b) (5 marks) Calculate the magnitude and direction of the force on $1\,m$ long section of wire 1, due to the current in wire 2.

   (c) (2 marks) Will wire 1 and wire 2 attract or repel each other?

   (d) (2 marks) If the current in wire 2 is reversed what will be the magnitude and direction of the force on wire 1?

5. A square wire loop with $2.00\,m$ sides is perpendicular to a uniform magnetic field $\vec{B}$, with half the area of the loop in the field as shown in Figure-4. The loop contains an ideal battery with $E_b = 20.0\,V$ and a resistor of $R = 25\Omega$. The magnitude of the field varies with time according to:

$$\vec{B} = 0.0420 + 0.870\,t$$

with $\vec{B}$ in tesla and t in seconds.

(a) $E_{in} = 1.74$ V

(b) $E_{net} = 18.26$ V

(c) $i = 0.73$ A

   (a) (7 marks) Calculate the magnitude and direction of the induced emf in the circuit.

   (b) (5 marks) Find out the net emf in the circuit.

   (c) (4 marks) What are the size and direction of the net current around the loop?

6. The LRC series circuit consists of a 300Ω resistor, a 60mH inductor and a 0.50μF capacitor as shown in Figure-5. It is connected to a 1×10^4 rad/s oscillator with a peak voltage, $\varepsilon_m = 50\,V$.

(a) $X_C = 200\ \Omega$

$X_L = 600\ \Omega$

$Z = 500\ \Omega$

(b) $I = 0.1$ A

$\phi = 53.13°$

(c) $V_R = 37.5$

$V_L = 75$ V

$V_C = 25$ V

(d) $f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{600\times200}} = 4.59\times10^{-4}$

$\omega = 2\pi f = 2.88\times10^{-3}$ rad/s

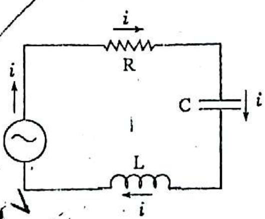


Figure 5: Question-6

   (a) (6 marks) Calculate the capacitive reactance X_C, inductive reactance X_L and the total impedance Z of the circuit.

   (b) (5 marks) Calculate the current amplitude I and the phase angle ϕ.

   (c) (3 marks) Determine the voltage amplitude V_R, V_L and V_C across each circuit element.

   (d) (2 marks) What is the resonant frequency of the circuit in both rad/s and in Hz?

7. (a) (4 marks) Find the longest and the shortest wavelengths of the Balmer series. Rydberg constant has the value of $R = 1.097\times10^7\,m^{-1}$.

   (b) (3 marks) Calculate the hydrogen atom's lowest level energy in eV. You can use the formula given below:

$$E_n = -\frac{me^4}{8\,\epsilon_0^2\,h^2}\left(\frac{1}{n^2}\right),\quad n = 1, 2, 3...$$

where the terms have their usual meanings.

ame: ______________________ ID#: ______________

(c) (5 marks) A spacecraft is moving with respect to the earth. A flashing light on the spacecraft generate a flash every 1.5 s. A person based on earth measures that the time between the flashes is 2.5 s. How fast is the spacecraft moving relative to the earth? 2.4×10^8 m/s

(d) (4 marks) What is the apparent length of a metre stick which is in the spacecraft to a person on earth?

0.6

8\. (a) A radioactive nucleus ^{226}Ra contains 3.0×10^{16} nuclei at $t = 0\,sec$. The half-life of the nucleus is 1.6×10^3 years.

i. (3 marks) What is the decay constant of ^{226}Ra nucleus? 9.33×10^{-4} y^{-1}

ii. (3 marks) Determine the activity at $t = 0\,sec$ for this ^{226}Ra nucleus. 1.299×10^{13} y^{-1}

iii. (3 marks) What is the decay rate 2.0×10^3 years later? 8.7×10^{12} y^{-1}

iv. (3 marks) How many undecayed nuclei will remain after 3.0×10^3years? 8.18×10^{15}

(b) (4 marks) Complete the following decay processes by stating what the symbol X represents.

i. $^{226}_{88}Ra \longrightarrow ^{222}_{86} Rn + X$

ii. $^{14}_{6}C \longrightarrow ^{14}_{7} N + X$

iii. $^{30}_{15}P \longrightarrow ^{30}_{14} Si + X$

iv. $^{231}_{90}Th^* \longrightarrow ^{231}_{90} Th + X$

SECTION B. Multiple Choice Questions

Answer any ten questions. Marks are as indicated: ________ /10

9\. i. Figure-6 shows three points a, b and c in the vicinity of two point charges. The charges have equal magnitudes. Rank the potentials V_a to V_c in order from most positive to most negative :

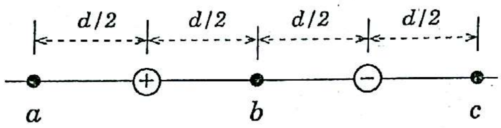


Figure 6: Question-9(i)

A. $V_a > V_b > V_c$ B. $V_b > V_c > V_a$ C. $V_a > V_c > V_b$ D. $V_b < V_a < V_c$

i. ____________

ii. A charged particle moves perpendicular to a magnetic field as shown in Figure-7. The direction of the magnetic field $\vec{B}$ is:

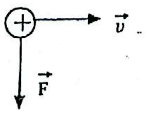


Figure 7: Question-9(ii)

A. Into the page B. Out of the page C. Upward D. Downward

ii. ____________

Name: ______________________ ID#: ______________

iii. Figure-8 shows three arrangements of RL circuits with magnitude of each resistor R and inductor L. Rank the three time constants τ_a to τ_c in the circuit a to circuit c, greatest first:

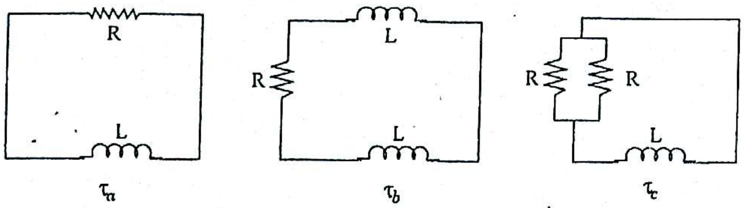


Figure 8: Question-9(iii)

A. $\tau_a > \tau_b > \tau_c$ B. $\tau_b = \tau_c > \tau_a$ C. $\tau_c = \tau_a > \tau_b$ D. $\tau_b > \tau_c > \tau_a$

iii. __________

iv. A magnetic field has the same direction and magnitude B everywhere. A circular area A is bounded by the loop of a wire. Which of the following statements is true concerning the magnitude of the magnetic flux that passes through this area?

A. It is zero B. It is BA C. Its maximum possible value is BA D. none of these.

iv. __________

v. Figure-9 shows four situations in which two very long wires are carrying the same current, although the directions of the currents are different. The point P in the drawings is equidistant from each wire. Which one (or more) of these situations give(s) rise to a zero net magnetic field at point P?

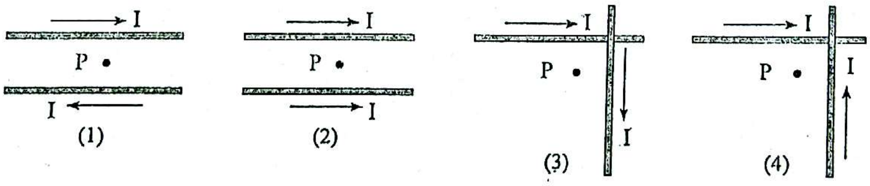


Figure 9: Question-9(v)

A. 2 and 4 B. Only 1 C. Only 2 D. 2 and 3

v. __________

vi. A positive point charge q_1 creates an electric field of magnitude E_1 at a spot located at a distance r_1 from the charge. The charge is replaced by another positive point charge q_2, which creates a field of magnitude $E_2 = E_1$ at a distance of $r_2 = 2r_1$. How is q_2 related to q_1?

A. $q_2 = 2q_1$ B. $q_2 = \frac{1}{2}q_1$ C. $q_2 = 4q_1$ D. $q_2 = \frac{1}{4}q_1$

vi. __________

vii. You have three resistors, each of which has a value of $R\,\Omega$. By connecting all the three resistors in various ways, which one of the following resistance values you cannot obtain?

A. $3R$ B. $\frac{3}{2}R$ C. R D. $\frac{1}{3}R$

vii. __________

viii. Each of the four phasor diagrams shown in Figure-10 represents a different circuit. V_0 and I_0 represent respectively, the maximum voltage of the generator and the maximum current in the circuit. Which circuit contains only a resistor?

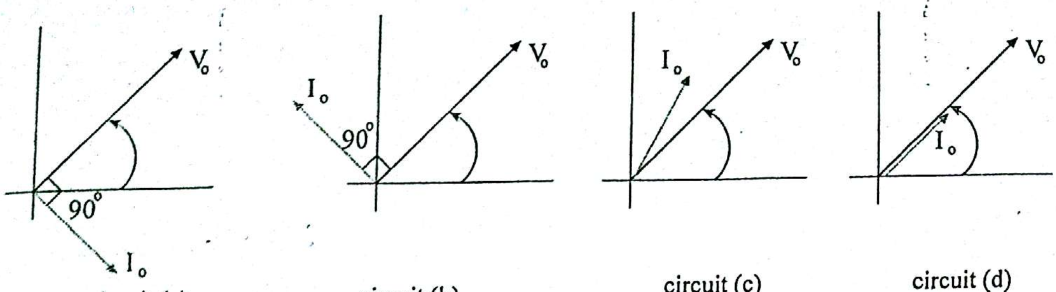


Figure 10: Question-9(viii)

A. circuit-(a) B. circuit-(b) C. circuit-(c) D. circuit-(d)

viii. ____________

ix. Which of the following quantities will two observers always measure to be the same, regardless of the relative velocity between the observers?

A. The time interval between two events
B. The length of an object
C. The speed of light in a vacuum
D. The relative speed between the observers

ix. ____________

x. A circular loop of a wire is stationary in a magnetic field $\vec{B}$ as shown in Figure-11. The current in the loop is:

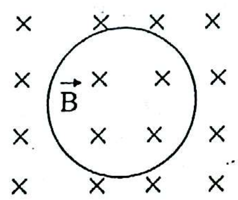


Figure 11: Question-9(x)

A. clockwise B. counterclockwise C. no current D. none of these

x. ____________

xi. The magnitude of the electric filed inside a capacitor having two positively charged parallel conducting plate is:

A. $E = \frac{\sigma}{\epsilon_o}$ B. $E = \frac{\sigma}{2\epsilon_o}$ C. $E = 0$ D. none of these

xi. ____________

xii. If a positive test charge q moves towards an increasing electric potential energy its velocity will:

A. increase B. decrease C. remain the same D. none of these

xii. ____________