The University of the West Indies

Examinations of December □ / April/May □ / July □ 2007

Course Code and Title:  P 14B Introductory Physics B

Date: Thursday, July 26, 2007  9:00am - 12:00pm  Time:

Duration: Three (3) Hours.

Materials required:

- Answer booklet:
  - Normal □
  - Special □
  - Not required □

- Calculator:
  - Programmable □
  - Non Programmable □

- Multiple choice answer sheets:
  - Numerical □
  - Alphabetical □  1-20 □  1-100 □

Auxiliary/Other material(s) - Please specify:

Candidates are permitted to bring the following items to their desks:

Instructions to Candidates: This paper has 6 pages & 10 questions.

Candidates are reminded that the examiners shall take into account the proper use of the English Language in determining the mark for each response.

Attempt SIX (6) questions, THREE (3) from each Section

Assume where necessary:

- Permittivity of free space, \( \varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1} \)
- Permeability constant, \( \mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1} \)
- Coulomb constant, \( k = 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2} \)
- Speed of light, \( c = 3 \times 10^8 \text{ m s}^{-1} \)
- Charge on the electron = \( 1.6 \times 10^{-19} \text{ C} \)
- Planck’s constant = \( 6.63 \times 10^{-34} \text{ J s} \)
1. (a) State Coulomb’s law in electrostatics. 

(b) Consider a finite line charge of length \( L \) lying along the \( X \) axis. The total charge is \( Q \) and is uniformly distributed from \( x = -0.5L \) to \( x = 0.5L \). The distance \( x \) is measured from the centre of the line charge.

(i) Show that the electric field at a point \( P \) on the axis which is at a distance \( x_p \) from the centre is,

\[
E_p = \frac{kQ}{x_p^2 - 0.25L^2}, \text{ for } x_p > 0.5L, \text{ where } k \text{ is Coulomb constant.}
\]

(ii) Determine the electric field for \( x_p \gg L \).

(iii) Is the result in (i) valid for \( -0.5L \leq x_p \leq 0.5L \). Give reasons for your answer. 

(c) A uniform line charge of linear charge density 3.5 nC m\(^{-1}\) extends over a length of 5 m.

(i) What is the total charge?

(ii) Determine the electric field at a point on the axis of the line charge located at a distance 9 m from one end.

(Hint: \( \int \frac{dY}{(A - Y)^2} = \frac{1}{(A - Y)} + \tan t \))

2. (a) (i) Define the capacitance of an isolated conductor in terms of the charge on it and the potential, and state the parameters on which the potential of the conductor depend.

(ii) State the relation between the electric field and the potential in differential form.

(b) A cylindrical capacitor consists of two conductors each of length \( L \). One conductor is a cylinder of radius \( R_1 \) and the other is a coaxial cylindrical shell of inner radius \( R_2 \). The space between the two cylinders is filled with air. Given that \( R_1 < R_2 \ll L \), and that the electric field at a radial distance \( R \) \((R_1 < R < R_2)\) from the common axis is

\[
E_R = \frac{Q}{2\pi\varepsilon_o LR}, \text{ where } Q \text{ is the total charge on the inner conductor and } \varepsilon_o \text{ is the permittivity of free space.}
\]

Contd..................
Show that the capacitance of the cylindrical capacitor is
\[
\frac{2\pi \varepsilon_0 L}{\ln \left( \frac{R_2}{R_1} \right)}
\]

[Hint: \( \int \frac{dy}{y} = \ln y + \text{const} \tan t \) ]

(7 marks)

(c) A Geiger tube, which is a cylindrical capacitor, consists of a wire of radius 0.25 mm, length 14 cm, and a coaxial cylindrical shell conductor of length 14 cm and radius 1.6 cm. The space inside the capacitor is filled with a gas of dielectric constant 1.2.

Determine (i) the capacitance,
(ii) the charge per unit length of the wire, if the potential difference between the wire and shell is 1.25 kV.

(7 marks)

3. (a) State Ampere’s law.

(1 mark)

(b) State the conditions that the linear path need to satisfy in order for Ampere’s law to be used to determine the magnetic flux density \( B \).

(2 marks)

(c) Use Ampere’s law to show that the magnetic flux density \( B \) at a distance \( R \) from a long straight wire carrying a current \( I \) is given by;

\[
B = \frac{\mu_0 I}{2\pi R}
\]

(4 marks)

(d) Three long straight parallel wires, \( X \), \( Y \) and \( Z \) are equally spaced 25 cm apart and carry currents of \( I_X = 10 \, \text{A} \), \( I_Y = 30 \, \text{A} \) and \( I_Z = 20 \, \text{A} \) respectively. The directions of the currents in \( X \) and \( Y \) are vertically up, and that of \( Z \) is vertically down. If the wire \( Y \) is located between \( X \) and \( Z \),

(i) Determine the magnitude and direction of the \( B \) field that the current \( I_X \) sets up at wire \( Y \).

(ii) Determine the magnitude and direction of the \( B \) field that the current \( I_Z \) sets up at wire \( Y \).

(iii) Calculate the magnitude and direction of the force per unit length that wire \( Y \) experiences.

(8 marks)

(e) Suggest changes in the currents in wires \( X \) and \( Z \) that would result in zero force per unit length on wire \( Y \).

(5 marks)
4. (a) State the relation between the **induced electric field** and the **rate of change of magnetic flux** through a closed loop. Define the symbols you may use.  
(4 marks)

(b) A long solenoid of radius R has n turns per unit length and carries a time-varying current that varies sinusoidally as \( I = I_0 \cos \omega t \), where \( I_0 \) is the maximum current and \( \omega \) is the angular frequency of the current source.

a) Determine the electric field outside the solenoid, at a distance \( r \) from its axis (\( r > R \)).

b) Determine the electric field inside the solenoid, at a distance \( r \) (\( r < R \)) from its axis.  
(8 marks)

(c) If \( R = 4 \text{ cm} \), \( I_0 = 100 \text{ mA} \), \( n = 1100 \text{ turns m}^{-1} \), and \( \omega = 2 \text{ rad s}^{-1} \), sketch;

(i) the variation of \( I \) with \( t \) for one full period,
(ii) the variation of the electric field with \( r \) for \( r > 4 \text{ cm} \), at \( t = 1 \text{ s} \),
(iii) the variation of the electric field with \( t \) at \( r = 1 \text{ cm} \).  
(2 + 3 + 3 marks)

5. (a) Draw the schematic circuit for a Full-Wave Bridge rectifier and sketch the output voltage.  
(8 marks)

(b) Given a series RLC circuit with following values: 
\( E_m = 100 \text{V} \), \( f = 10 \text{KHz} \), \( Z = 1000 \Omega \), \( \phi = 45^\circ \), \( C = 10 \text{nF} \).
The symbols have their usual meanings.

Determine:

(i) values for \( R \) and \( L \);
(ii) values for \( V_R \), \( V_C \), and \( V_L \);
(iii) when the current in the circuit has the maximum value and calculate this value.  
(4 + 5 + 3 marks)

**SECTION B**

**ELECTRONICS & MODERN PHYSICS**

(Questions 6-10)

6. (a) Convert the following hexadecimal numbers to decimal
\( \text{EB}_{16}, 5C2_{16}, 700_{16}, \text{BB}_{16} \)

(b) Convert the following decimal numbers to hexadecimal numbers
\( 256, 832, 1580, 2800 \)

(c) Convert the decimal numbers to octal
\( 256, 832, 1580, 2800 \)  
(8 + 6 + 6 marks)
7. (a) For the logic circuit drawn below deduce the logic expression

(6 marks)

(b) Simplify the logic expression found above using Boolean algebra and DeMorgan’s theorems.

(8 marks)

(c) Draw the new logic circuit for the simplified logic expression found at (b) and give the truth table.

(6 marks)

8. (a) Radiation of appropriate frequency produces photoelectrons from a metal surface whose work function is 2.0 eV. A reverse potential of 2.5 volts is found to reduce the photo-electric current to zero. Calculate
(i) the maximum kinetic energy in Joules, that these photoelectrons can have;
(ii) the frequency of the incident radiation;
(iii) the mean work needed for the photoelectron to escape from the metal, if the mean energy per photoelectron is measured to be 0.96 x 10^{-19} J.

(3+3+4 marks)

(b) State de Broglie’s hypothesis about the dual nature of material particles. Hence show that this hypothesis may be used to explain Bohr’s postulate concerning the quantization of angular momentum:

\[ L = \frac{nh}{2\pi} \]

(2+8 marks)
9. (a) Define in one or two sentences each of the following:
(i) proper time
(ii) proper length

(3+3 marks)

(b) Consider the reference frame S at rest and another frame S' moving along the x axis of S at a constant speed of v. Write down the transformation equations for x', y', z' and t' measured in S' in terms of x, y, z and t measured in S.

(4 marks)

A particle accelerator tube is 4 km long according to you at rest. Electrons move through the tube at a constant speed so that \(1 - \frac{v^2}{c^2} = 10^{-6}\)

(i) According to you, how long do the electrons take to complete their trip?
(ii) In the frame of reference of the electrons, what is the length of the tube?
(iii) What is the proper time interval for the electrons' trip.

(4+3+3 marks)

10. (a) Show that the allowed energy levels for an electron in an infinite potential well of width L is given by,

\[ E = \left( \frac{\hbar^2}{8mL^2} \right) n^2 \]

where the symbols have their usual meanings.

(6 marks)

(b) (i) If \(\psi^2(x)\) is the probability density what is the physical interpretation of \(\psi^2(x)dx\) ?
(ii) Use that interpretation to justify the equation

\[ \int_{x=0}^{x=L} \psi^2(x)dx = 1 \]

(iii) Hence if the wave function for an electron in an infinite potential well of width L is given by

\[ \psi(x) = A \sin \left( \frac{n\pi x}{L} \right) \]

show that \(A = \frac{2}{\sqrt{L}}\)

(You may assume that \(\int \sin^2 y \, dy = \frac{1}{2} y - \frac{1}{2} \sin y \cos y + C\))

(2+4+8 marks)

END