NATIONAL UNIVERSITY OF SINGAPORE

PC1143 PHYSICS III

(Semester II: AY 2005-6, April)

Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **5 short** questions in Part I and **3 long** questions in Part II. It comprises **5** printed pages.
2. Answer **ALL** the questions in Part I and any **TWO** questions in Part II.
3. Answers to all questions are to be written in the answer books.
4. This is a CLOSED BOOK examination.
5. The total marks for Part I is 40 and that for Part II is 60.

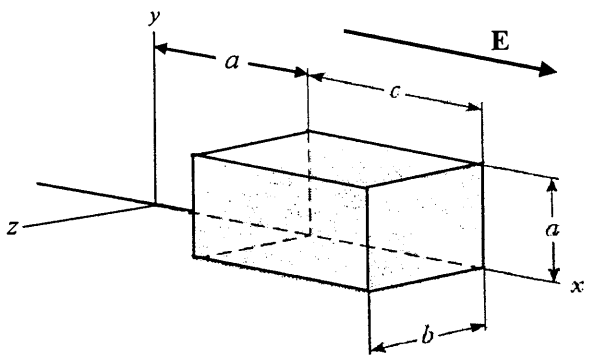
PART I

This part of the examination paper contains **five (5)** short-answer questions on page 2.

Answer **all** questions.

1. Two uniform metal plates of area A are a distance d apart. One plate has a positive charge of q and the other has a negative charge of $-q$. Stating any assumptions you make, derive an expression for the capacitance of this system using Gauss's Law.

2. A closed surface with dimensions $a = b = 0.40$ m and $c = 0.60$ m is located as shown below. The electric field throughout the region is non-uniform and given by $\mathbf{E} = (3.0x + 2.0\,x^2)\,\mathbf{i}$ N/C, where x is in meters. Calculate the net electric flux leaving the closed surface. What is the net charge within the surface ?



3. A spherically symmetric charge distribution has a charge density given by $\rho = a/r$, where a is a constant. Find the electric field as a function of r. (HINT Note that the charge within a sphere of radius R is equal to the integral of $\rho\,dV$, where r extends from 0 to R).

4. A series RLC circuit contains the following components: $R = 150\ \Omega$, $L = 250$ mH, $C = 2.0\ \mu$F, and a generator which supplies a maximum a.c. voltage of $V_{max} = 210$ V and operating at 50 Hz. Calculate the:
   (a). Inductive reactance.
   (b). Capacitative reactance.
   (c). Impedance.
   (d). Maximum current.
   (e). Phase angle between the current and the generator voltage.

5. An important news announcement is transmitted by radio waves to people 1000 km away from the radio station who are sitting 1.0 m away from their radios. The announcement is also heard directly by people in the newsroom who are 3.0 m away from the newscaster. Who receives the news first ? Explain your answer.

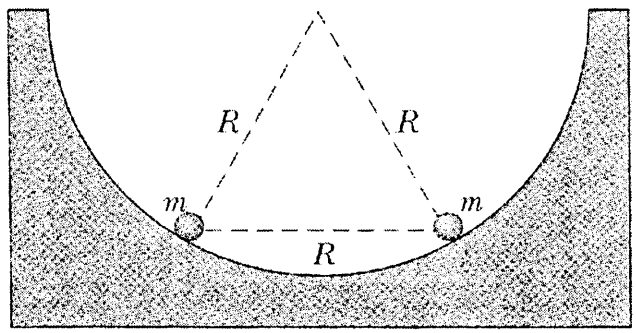
END OF PART I

PART II

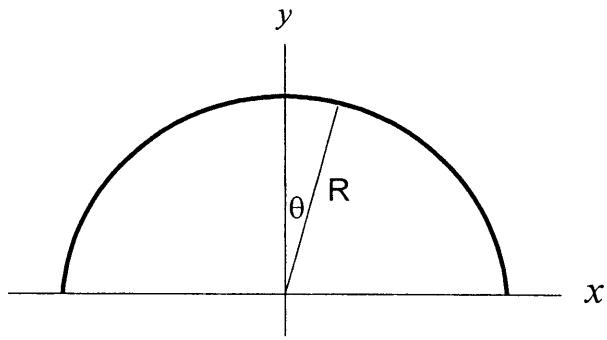
This part of the examination paper contains **three (3)** long questions on pages 3 to 5.

Answer **two out of three** questions.

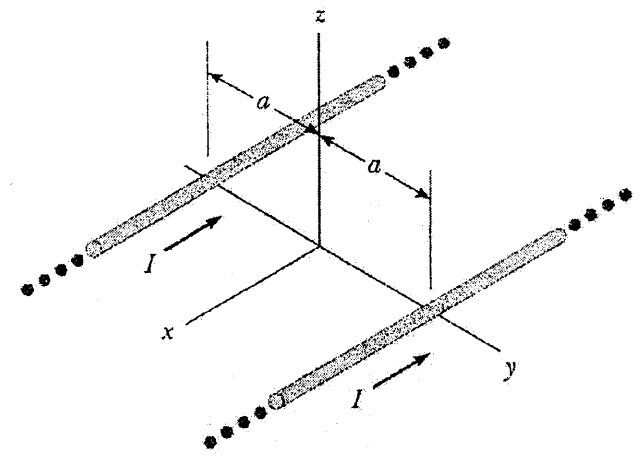
6. (a). Two identical beads each have a mass m and charge q. When placed in a hemispherical bowl of radius R with frictionless, non-conducting walls, the beads move and at equilibrium they are a distance R apart. Find an expression for the charge on each bead.



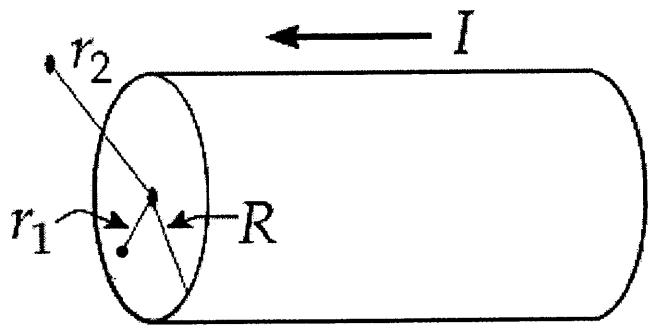
(b). A line of positive charge is formed into a semicircle of radius R = 60.0 cm, as shown below. The charge per unit length along the semicircle is given by $\lambda=\lambda_o\cos\theta$. The total charge on the semicircle is 12.0 μC. Calculate the total force acting on a charge of 3.0 μC placed at the centre of curvature (i.e. the coordinate $x=0$, $y=0$ in the figure below).



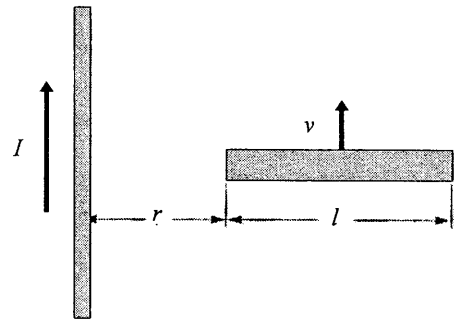
7. (a). In the sketch below, both currents are in the negative x direction. (i) Sketch the magnetic field pattern in the yz plane. (ii) At what distance d along the z axis is the magnetic field a maximum ?



(b). A long, cylindrical conductor of radius R carries a current I as shown below. The current density J varies over the cross-section of the conductor according to $J = br$, where b is a constant and r is the radius. Find an expression for the magnetic field **B** (i) at a distance $r_1 < R$ and (ii) at a distance $r_2 > R$, measured from the axis.



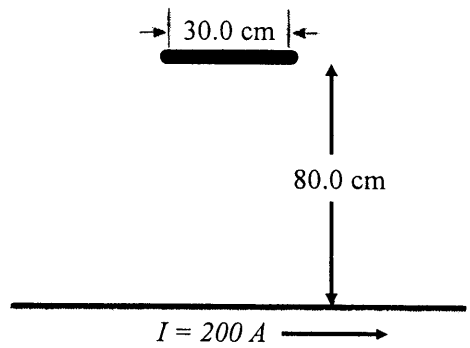
8. (a). A conducting rod of length l moves with a velocity v parallel to a long wire which carries a constant current I. The axis of the rod is maintained perpendicular to the wire with the near end a distance r away, as shown below.



Show that the magnitude of the electromotive force ε induced in the rod is:

$$|\varepsilon| = \frac{\mu_o I}{2\pi} v \ln\left(1+\frac{l}{r}\right)$$

(b). A wire which is 30.0 cm long is held parallel to, and 80.0 cm above, a long wire which carries a constant current of 200 A and is resting on the floor, as shown below. The 30.0 cm long wire is released and falls, remaining parallel with the current-carrying wire as it falls. Assume that the falling wire accelerates at g = 9.8 m/s^2, derive an equation for the electromotive force ε which is induced in it. Express your result as a function of the time t after the wire is dropped. What is the induced electromotive force 0.30 seconds after the wire is released ?



(M.B)

END OF PART II

END OF PAPER