UNIVERSITY OF RUHUNA

B.Sc. General Degree Level II (Semester II) Examination – DECEMBER 2014

Subject: PHYSICS
Course Unit: PHY2214

Time: 02 hours & 30 minutes

Part II

Answer at least 01 (ONE) question from each of the parts A, B and C.

Answer FIVE (05) Questions only.

(All symbols have their usual meaning)

$$h = 6.626\times10^{-34}\ \mathrm{Js}$$
$$\varepsilon_0 = 8.854\times10^{-12}\mathrm{C^2N^{-1}m^{-2}}$$
$$e = 1.6\times10^{-19}\mathrm{J}$$
$$c = 3\times10^{8}\mathrm{ms^{-1}}$$
$$m_e = 9.1\times10^{-31}\ \mathrm{kg}$$

Laplace equation in cylindrical coordinates $\nabla^2 V = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 V}{\partial \varphi^2} + \frac{\partial^2 V}{\partial z^2} = 0$

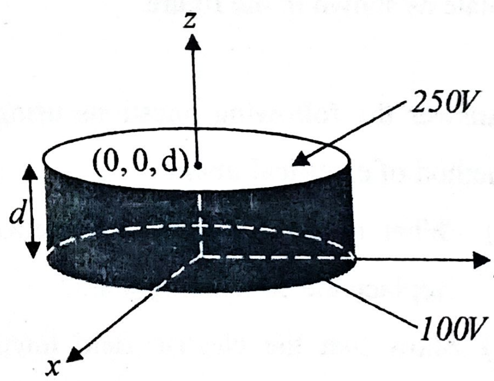
Del operator in cylindrical coordinates $\nabla = \frac{\partial}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial}{\partial \varphi}\hat{\varphi} + \frac{\partial}{\partial z}\hat{z}$

Part A

1. a) Starting from the differential form of the Gauss' law, obtain Poisson's and Laplace's equations.

   b) Discuss the importance of Poisson's and Laplace's equations.

   c) Two conducting circular disks with radius 2 m are separated parallel by d m as shown in the figure. The potentials on each plate are indicated in the diagram.

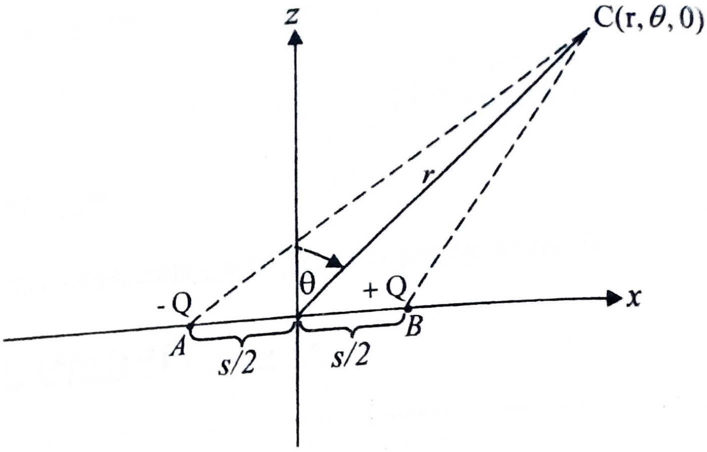


   (i) Find the electric potential (V) and electric field intensity ($\vec{E}$) between disks in terms of cylindrical coordinates.

   (ii) Find V and $\vec{E}$ at the point $(1\mathrm{m}, \frac{\pi}{2}, \frac{d}{2})$.

   (iii) If the region between the disks is filled by a dielectric material of $\epsilon_r = 2.2$, find the electric displacement vector ($\vec{D}$) between disks.

2. An electric dipole is located along the x axis as shown in the figure. If $r >> s$, the electric potential at the point $C(r, \theta, 0)$ is given by $V = \frac{Qs\, sin\theta}{4\pi\epsilon_0 r^2}$.



(i) The electric dipole moment can be written as $\vec{P} = Q\vec{s}$. Hence, show that the electric potential at the point $C(r, \theta, 0)$ can also be written as

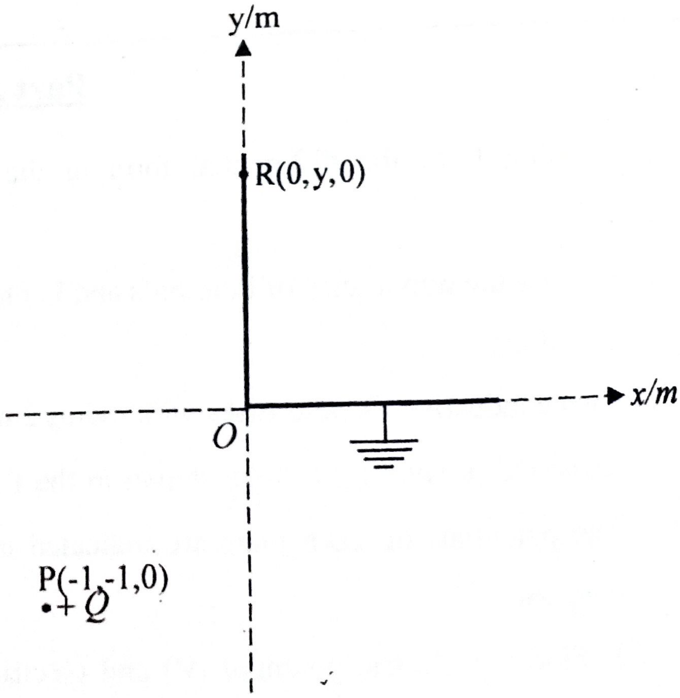
$$V = \frac{\vec{P}.\hat{r}}{4\pi\varepsilon_0 r^2} = \frac{\vec{P}.\vec{r}}{4\pi\varepsilon_0 r^3}.$$

(ii) Using the above result, obtain an expression for the scalar potential at the point $C(x, 0, z)$ in terms of Cartesian coordinates.

(iii) Find the x, y and z components of electric field at the point $C(x, 0\ z)$.

(iv) If $Q = 1\text{C}$ and $s = 1\text{cm}$ find V and $\vec{E}$ at the point $(1\text{m}, 0, 1\text{m})$.

3. A point charge $+Q$ is placed at point $P(-1\text{m}, -1\text{m}, 0)$ near an infinitely large, bent into a L shape, grounded, conducting plate as shown in the figure.



Answer the following questions using the method of electrical images.

(i) What image charge(s) are needed to replace the conducting plate?

(ii) Show that the electric field intensity at $R(0, y, 0)$ is given by

$$\vec{E}_R = \frac{Q}{2\pi\epsilon_0}\left(\frac{1}{(y^2 + 2y + 2)^{3/2}} - \frac{1}{(y^2 - 2y + 2)^{3/2}}\right)\hat{\imath}$$

(iii) Find the location of the point where $\overrightarrow{E_R} = 0$ on the axis oy.

(iv) If $Q = 1C$, find the electric field intensity at point $(1\text{m}, 0, 0)$.

Part B

4. a) (i) What is a photon? State its properties.

   (ii) Mercury vapour absorbing a photon of wavelength 140 nm emits two photons. If one has a wavelength 180.5 nm, what is the wavelength of the other?

   b) In an experiment, the work function of potassium surface is found to be 2.1 eV.

   (i) Calculate the threshold wavelength.

   (ii) What should be the wavelength of incident radiation if the kinetic energy of the ejected electron is 0.43 eV?

   (iii) Does every photon incident on a photo cathode cause emission of an electron?

5. a) Derive expressions for Compton shift and wavelength of scattered photon.

   b) What is Compton wavelength? Determine its value.

   c) X-rays of wavelength $0.2\,\mathring{A}$ are scattered from a Carbon target. Find maximum shift in wavelength and maximum energy of recoil electron.

6. a) (i) What is meant by binding energy of a nucleus?

   (ii) Calculate the binding energy per nucleon in the isotope $^{12}_{6}C$. Assume that the mass of the isotope is exactly $12\,u$ and the masses of the proton and neutron are $1.007276\,u$ and $1.008665\,u$ respectively.

   b) (i) What is meant by half – life period?

   (ii) Derive an expression for the half-life period of radioactive decay.

   (iii) A sample containing 50 g of Radium – 226 has 6.5 g after 5000 years. Determine the half – life of Radium – 226.

Part C

7. (i) What is meant by Time Dilation?

(ii) The clock moves at a speed v w.r.t. stationary observer in the rest frame. At what speed does a clock move if it runs at a rate, which is one-half the rate of a clock at rest?

(iii) A muon has a lifetime of 2×10^{-6} s in its rest frame. It is created 100 km above the earth and moves towards earth at a speed of 2.97×10^{8} ms^{-1}. At what altitude does it decay? According to the muon, how far did it travel in its brief life?

8. a) Consider two observers O and O′, each using their own Cartesian coordinates system to measure space and time intervals. O uses (t, x, y, z) and O′ uses (t′, x′, y′, z′). The x-axis and the x′-axis are collinear, the z-axis is parallel to the z′ -axis, and the y-axis parallel to the y′-axis. O measures O′ to move at velocity v along the coincident xx′ - axes.

(i) Write down the Lorentz transformation and inverse Lorentz transformation equations.

(ii) Drive the velocity transformation equations for the x and y component.

b) As seen from Earth, two spaceships A and B are approaching along perpendicular directions. If A is observed by a stationary Earth observer to have velocity $u_y = -0.9c$ and B to have velocity $u_x = +0.9c$, determine the speed of ship A as measured by the pilot of ship B.

9. Consider the two systems, one is the lab frame and second one is in the frame moving to the left with speed u. In the lab frame the two identical particles of mass m both have identical speed u and head directly towards one another. They collide and stick together to form a mass M which is at rest. In the moving frame, the mass m moves to the right with velocity v collide with the mass m is at rest and then form a mass M moves to the right with speed u.

(i) Using the velocity transformation find the velocity v in terms of u.

(ii) Find the Lorentz factor (γ) associated with the velocity v.

(iii)Apply the energy and momentum conservation for the second system and hence show that the mass M is equal to the $\dfrac{2m}{\sqrt{1-u^2/c^2}}$.

(iv)Two protons approach each other from opposite direction, travelling with equal and opposite speeds 0.6c. They collide to form a single particle is at rest. Show that the mass of the particle formed is significantly more than sum of the initial masses. The proton mass is 1.67×10^{-27} kg.

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