UNIVERSITY OF RUHUNA

eneral Degree Level II (Semester II) Examination – NOVEMBER/DECEMBER 2015

…: PHYSICS

…Unit: PHY 2214

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)

…constant, $h = 6.626 \times 10^{-34}$ Js

…of the electron, $e = 1.6 \times 10^{-19}$ C

…of the electron, $m_e = 9.1 \times 10^{-31}$ kg

…ability of free space, $\varepsilon_0 = 8.854 \times 10^{-12}\ C^2\,N^{-1}\,m^{-2}$

Rydberg constant, $R = 1.097 \times 10^{7}\ m^{-1}$

Speed of light, $c = 3 \times 10^{8}\ ms^{-1}$

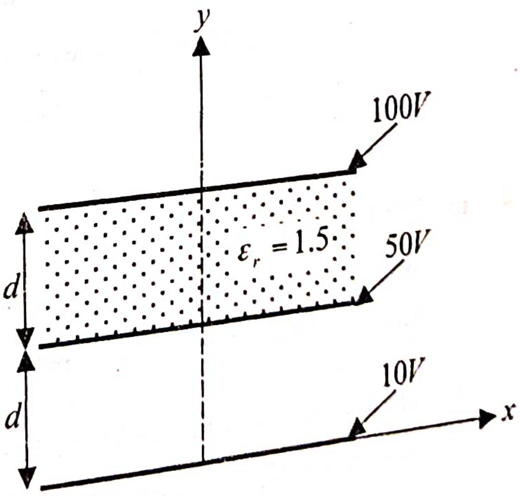
Coulomb constant, $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}\ Nm^2C^{-2}$

Part A

1. Write down differential form of Gauss' law, Poisson's equation and Laplace's equation.

a) The electric displacement vector in a region is given by $\vec{D} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$. Find the volume charge density (ρ) in that region.

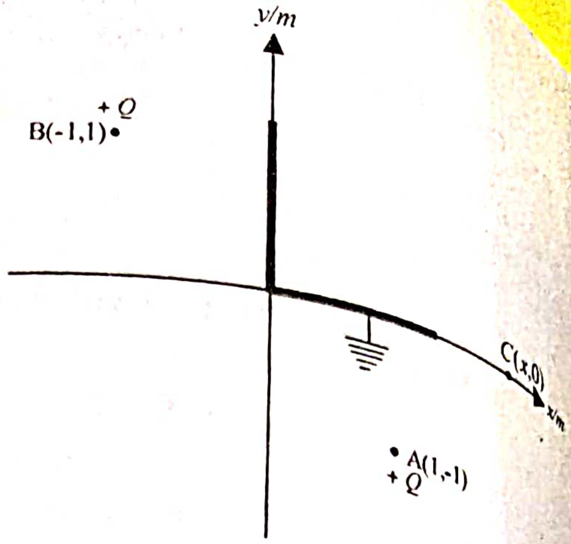
b) Three infinite, thin conducting plates are placed parallel in a charge free region as shown in the diagram. Potential on each plate is indicated in the diagram. The relative permittivity of the region between upper two plates is 1.5.



(i) Find the electric potential (V) and electric field intensity ($\vec{E}$) in the regions $0 < y < d$ and $d < y < 2d$.

(ii) If $d = 1.5$ m, find V, $\vec{D}$ and $\vec{E}$ at the point (1m, 2m, 1m).

2. Two point charges are placed at points $A(1\text{m}, -1\text{m})$ and $B(-1\text{m}, 1\text{m})$ near an L shaped infinitely long, grounded, conducting plate as shown in the figure.



Answer following questions using the method of electrical images.

(i) Locate in the diagram, image charge(s) needed to replace the conducting plate.

(ii) Show that the electric field intensity at point $C(x,0)$ is given by

$$\vec{E}_C = \frac{Q}{2\pi\epsilon_0}\left(\frac{1}{(x^2-2x+2)^{3/2}} - \frac{1}{(x^2+2x+2)^{3/2}}\right)\hat{j}$$

(iii) At which point on the x – axis, $E_C = 0$?

(iv) If $Q = 5C$, find the electric field intensity at point $(1\text{m}, 0)$.

3. a) Write down Maxwell's equations in electrodynamics for a free space.

b) If the electric field intensity vector in a free space is $\vec{E} = E_0 \sin(\omega t - \beta z)\hat{\imath}$, use Maxwell's equations in electrodynamics to determine $\vec{D}$, $\vec{B}$ and $\vec{H}$.

c) Sketch the variations of $\vec{E}$ and $\vec{H}$ along z-axis at t = 0.

Part B

4. a) What is Photo-electric effect?

Sketch a labeled diagram of an apparatus to demonstrate photo-electric effect. Write down three important findings of the photo-electric effect.

b) The threshold wavelength for photo-electric emission of tungsten is 230 nm. Electrons are ejected from the tungsten surface with a velocity of $5 \times 10^5 \text{ ms}^{-1}$.

(i) What is the kinetic energy of the ejected electrons?

(ii) Find the wavelength of incident light that ejects electrons with above velocity.

5. a) Explain briefly, formation of first two series (i.e. Lyman and Balmer) of the hydrogen spectrum. Sketch them in an energy level diagram.

b) Using Bohr theory, derive the expression for the wavelength of the emitted radiation when an electron falls from an outer orbit n_2 to an inner orbit n_1. The total energy of an electron in the n^{th} orbit is $E_n = -Rhc\frac{1}{n^2}$. Hence, obtain equations for Lyman and Balmer series of the hydrogen spectrum. Here R is the Rydberg constant.

c) A beam of electrons bombards a sample of hydrogen and produces a various series of line spectrum.

(i) Calculate largest and shortest wavelengths of the Lyman series.

(ii) How much energy is released when an electron jumps from $n = 3$ to $n = 1$ in the hydrogen atom? Ionization energy of hydrogen is 13.6 eV.

6. a) (i) What is meant by radioactivity?

(ii) Discuss, briefly properties of α, β *and* γ rays emitted in the radioactivity.

b) Derive an expression for the decay rate (activity) of a radioactive sample.

c) A GM tube placed close to a radium source gives an initial average corrected count rate of $334\ s^{-1}$.

(i) The GM tube detects 10 % of the radiation. What is the initial activity?

(ii) Initially there were 1.5×10^9 nuclei in the sample. What is the decay constant?

(iii) What is the half-life of the radium in days?

Part C

7. a) Write down the expression for length contraction. Define each term in the expression assuming that a frame S′ travels with a velocity v relative to a frame S along z-axis.

b) A rocket travels from the Mars to Neptune at 0.9c velocity relative to the solar system. The distance between Mars and Neptune is 4.27×10^{12} m.

(i) In which reference frame is proper length measured?

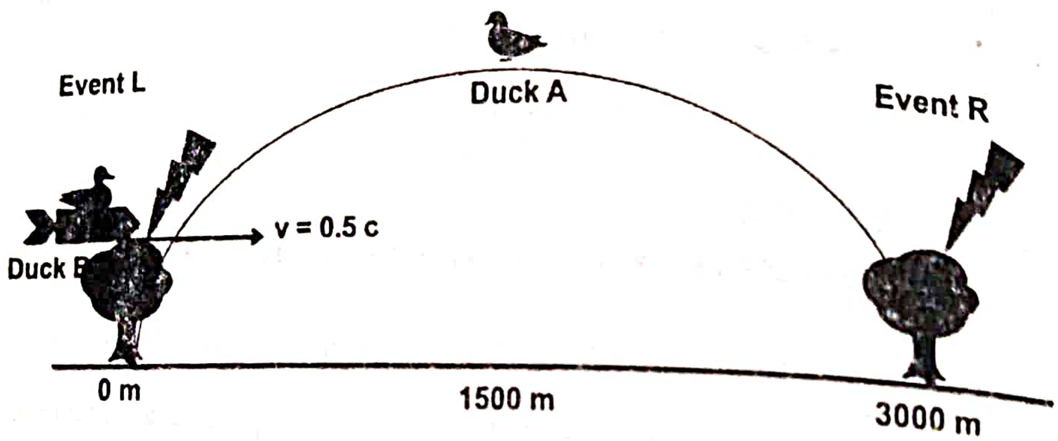
(ii) Find the Lorentz factor.

(iii) What is the distance between the Mars and Neptune as measured by an astronaut on the rocket?

c) (i) Write down the velocity transformation equations for a moving particle in x-direction.

(ii) Rocket A from the earth tries to catch up the rocket B of velocity 0.9c relative to earth. Velocity of rocket A is 0.95c. What is the velocity of rocket A with respect to B? Assume that both rockets are traveling in the same direction.

8.



Consider the above diagram. Duck B flies in a rocket at $v = 0.5c$ to the right as shown. In the reference frame of Duck A, the two lightning bolts hit the trees simultaneously at $t = 0$. The left tree is struck just as Duck B passes by it. Duck B is at the origin of her reference frame and at $t' = 0$, just as Duck B passes the left tree.

(i) Find space-time coordinates of event R and event L

(a) in Duck A's reference frame and

(b) in Duck B's reference frame.

(ii) Explain your answer of event R in Duck B's reference frame.

(iii) Find space-time coordinates of the event, when Duck B is passing the right tree

(a) in Duck A's reference frame and

(b) in Duck B's reference frame.

(iv) What is the distance between the trees in Duck B's reference frame?

9.

(i) Using the relativistic momentum ($p = \gamma m_0 v$) and the Lorentz factor $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$, show that velocity can be written as $v = \frac{c}{\sqrt{1 + \left(m_0 c/p\right)^2}}$.

(iii) Hence, show that relativistic momentum can be written as $p = \frac{\sqrt{K(K + 2m_0c^2)}}{c}$. Here $K = (\gamma - 1)m_0c^2$ is the kinetic energy of a particle with rest mass m_0 and moving with speed v.

(iv) An electron e^- with kinetic energy 1 MeV collides head-on with a positron e^+ at rest. In the collision, the two particles annihilate with each other to produce two photons of equal energy, each traveling at angles θ with the electron's direction of motion. Determine energy E, momentum p and angle of emission θ of each photon. (reaction is $e^- + e^+ \rightarrow 2\gamma$). Rest mass of the electron is 0.511 MeV/c^2.

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