UNIVERSITY OF RUHUNA

B.Sc. General Degree Level II (Semester II) Examination – March/April 2019

Subject: PHYSICS

Course Unit: PHY2214

Time: 02 hours & 30 minutes

Part II

Answer FIVE (05) Questions only.

(All symbols have their usual meaning)

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

$\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$

$\mu_0 = 4\pi \times 10^{-7} Hm^{-1}$

$e = 1.6 \times 10^{-19} C$

$c = 3 \times 10^8 ms^{-1}$

$m_e = 9.1 \times 10^{-31}$ kg

$1\ u = 931.5$ MeV

$m_p = 1.6726 \times 10^{-27}$ kg

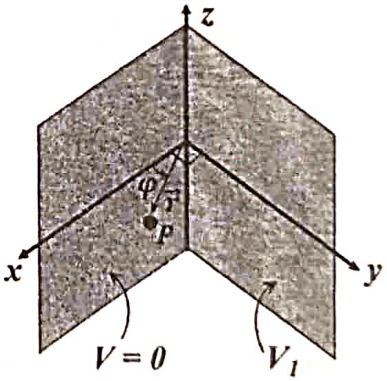
In cylindrical coordinates,

Laplace's equation: $\nabla^2 V = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 V}{\partial \varphi^2} + \frac{\partial^2 V}{\partial z^2} = 0$

Del operator: $\vec{\nabla} = \frac{\partial}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial}{\partial \varphi}\hat{\varphi} + \frac{\partial}{\partial z}\hat{z}$

1. a) Starting from the differential form of the Gauss' law, obtain Poisson's and Laplace's equations. **(05 marks)**

b) Two infinitely long conducting planes have been put together such that the planes are insulated along z-axis as shown in the figure. The plane at $y = 0$ is kept at ***zero potential*** and the other plane at $x = 0$ is kept at a constant potential of V_1.



(i) Solve the Laplace's equation to find the potential at a point P(r, φ) between the planes $\left(0 < \varphi < \frac{\pi}{2}\right)$. **(08 marks)**

(ii) Derive an expression for the electric field intensity $\vec{E}$ at the point P(r, φ). **(04 marks)**

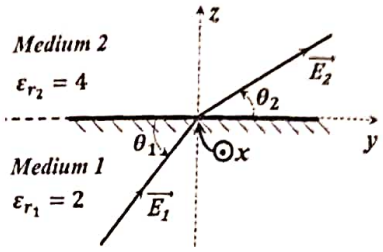
(iii) If the space between the conducting planes are filled with a medium of relative permittivity $\varepsilon_r = 2.5$, find the electric displacement vector $\vec{D}$ at point P(r, φ).

(04 marks)

(iv) Calculate the electric field intensity and the electric displacement vector at a distance of **1 m** from the *z-axis* on the *horizontal plane* (*x-y* **plane**) if $V_1 = 100$ *Volts*.

(04 marks)

2. a) Two dielectric media are separated by a *charge free boundary* on the *x-y* plane as shown in the given figure. The electric field vector in the *medium 1* is given by $\overrightarrow{E_1} = 3\hat{\imath} + 4\hat{\jmath} + 2\hat{k}$. Relative permittivities of *medium 1* and *medium 2* are $\varepsilon_{r_1} = 2$ and $\varepsilon_{r_2} = 4$, respectively.



(i) Calculate $\overrightarrow{D_1}$, $\overrightarrow{E_2}$ and $\overrightarrow{D_2}$. **(10 marks)**

(ii) Find the angles θ_1 and θ_2 between the field vectors and a tangent to the interface.

(04 marks)

b) (i) Write down Maxwell's equations in electrodynamics for a free space.

(04 marks)

(ii) If the magnetic field intensity vector in *free space* is given by $\vec{H} = H_0 \sin(\omega t - \beta z)\,\hat{\imath}$, use Maxwell's equations in electrodynamics to obtain expressions for $\vec{B}$, $\vec{E}$ and $\vec{D}$ in free space. **(07 marks)**

3. a) (i) Write down de-Broglie equation. **(03 marks)**

(ii) If a matter particle of mass m has a kinetic energy E, then derive an expression for its de-Broglie wavelength in terms of E. **(04 marks)**

(iii) Calculate de-Broglie wavelength of an electron whose kinetic energy is **100 eV**. **(04 marks)**

b) (i) What is meant by photo-electric effect? **(03 marks)**

(ii) Write down Einstein's photo-electric equation naming all the terms. **(03 marks)**

(iii) Light of wavelength **2200 Å** falls on a photo-sensitive material having work function **4.0 eV**. What is the kinetic energy of the fastest electron in **electron-Volts**? What is the kinetic energy of the slowest electron that could be emitted from this material? **(08 marks)**

4. a) (i) What is meant by half-life period of a radioactive substance? **(03 marks)**

(ii) Derive an expression for the half-life period (T) of a radioactive substance in terms of the radioactive decay constant (λ). **(06 marks)**

(iii) **2 g** of radium is reduced by **2 mg** in **5 years** through alpha decay process. Calculate the half-life period of radium. **(04 marks)**

b) (i) What is meant by **Q-value** of a nuclear reaction? **(03 marks)**

(ii) How do you determine if a nuclear reaction is either *exothermic* or *endothermic* according to the Q-value of that reaction? **(02 marks)**

(iii) Consider the following nuclear reaction:

$$^{236}_{92}\mathbf{U} \rightarrow {}^{141}_{56}\mathbf{Ba} + {}^{92}_{36}\mathbf{Kr} + 3\,(^{1}_{0}\mathbf{n})$$

($^{236}_{92}\mathrm{U} = 236.045568\,u$, $^{141}_{56}\mathrm{Ba} = 140.914411\,u$, $^{92}_{36}\mathrm{Kr} = 91.926156\,u$ and $^{1}_{0}\mathrm{n} = 1.008664\,u$)

Calculate the Q-value of the above nuclear reaction. **(07 marks)**

Is it exothermic or endothermic?

5. a) What is meant by Time Dilation? **(03 marks)**

b) Write down the equation for Time Dilation and define all the terms. **(03 marks)**

c) A rocket ship leaves Earth at a speed of 0.6c. When a clock at the origin of the rocket's frame says 1 hour as elapsed, the rocket sends a light signal back to Earth. Assume that the clocks on the Earth and the rocket are set to $t = t' = 0$ when the rocket leaves the Earth.

(i) Sketch the diagram of the Earth and rocket system and identify the inertial frames. **(03 marks)**

(ii) Find the Lorentz Factor. **(03 marks)**

(iii) According to Earth clock, when was the signal sent from the rocket? **(04 marks)**

(iv) Calculate the distance traveled by the signal from rocket to Earth relative to the observer on Earth. **(04 marks)**

(v) Find the time on the Earth clock, When the signal arrives on Earth? **(05 marks)**

6. a) Starting from the relationship, $E = m_0c^2$, for the rest energy of a particle obtain the relationship $E^2 = p^2c^2 + m_0^2c^4$ for a particle moving at relativistic speed. **(08 marks)**

b) Write down the E and p relationship for a massless particle. **(02 marks)**

c) Calculate the relativistic momentum of a proton travelling at the speed of 0.999c. **(05 marks)**

d) Calculate the speed of a 1.00 μg particle of dust that has the same momentum as a proton moving at 0.999c. **(07 marks)**

e) Comparing the speed of the dust particle in part (d) and the speed of the proton, what can you say about the mass of a proton in compared with the mass of the dust particle? **(03 marks)**

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