UNIVERSITY OF RUHUNA

B.Sc. General Degree Level II (Semester II) Examination – September/October 2020

Subject: PHYSICS
Course Unit: PHY2214

Time: 02 hours & 30 minutes

Part II

Answer FIVE (05) Questions only.

(All symbols have their usual meaning)

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

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

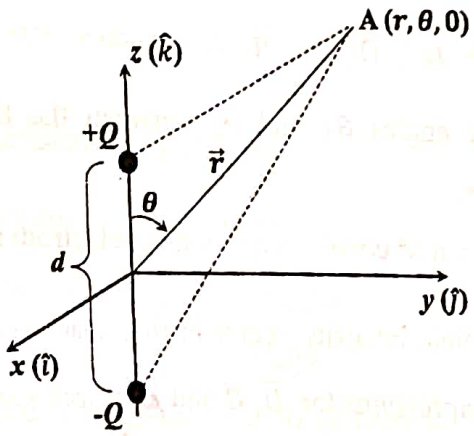
$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}

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

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

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

1. An electric dipole is located along the z-axis as shown in the figure. If $r >> d$, the electric potential at the point A $(r, \theta, 0)$ is given by $V = \frac{Qd\,Cos\theta}{4\pi\epsilon_0 r^2}$.



(i) The electric dipole moment can be written as $\vec{P} = Q\vec{d}$. Hence, show that the electric potential at the point A $(r, \theta, 0)$ can also be written as $V = \frac{\vec{P}.\hat{r}}{4\pi\epsilon_0 r^2} = \frac{\vec{P}.\vec{r}}{4\pi\epsilon_0 r^3}$.

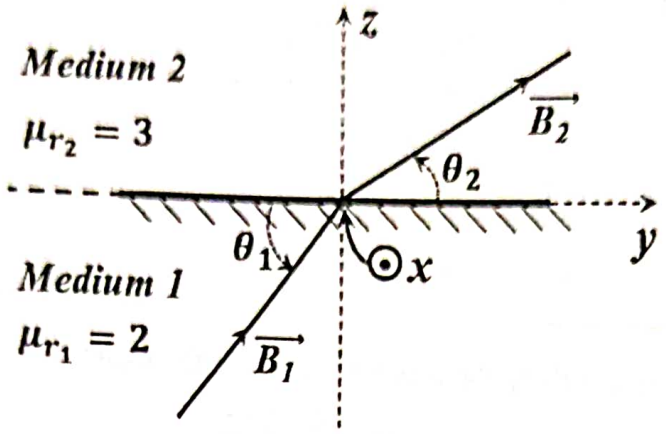
(06 marks)

(ii) Using the above result, obtain an expression for the scalar potential at the point A (x,y,z) in terms of Cartesian coordinates. **(05 marks)**

(iii) Find x, y, z components of the electric field $\vec{E}$ at the point A (x, y, z). **(08 marks)**

(iv) If Q = 1C and d = 2 cm, find V and $\vec{E}$ at the point (1m, 2m, 1m). **(06 marks)**

2. a) Two magnetic media are separated by a current free interface as shown in the given figure. The magnetic field vector in the *medium 1* is given by $\vec{B}_1 = 2\hat{i} + \hat{j} + 4\hat{k}$. Relative permeabilities of *medium 1* and *medium 2* are given by $\mu_{r_1} = 2$ and $\mu_{r_2} = 3$, respectively, where $\vec{B}$ is the Magnetic flux density and $\vec{H}$ is the Magnetic field intensity.



(i) Calculate $\vec{H}_1$, $\vec{H}_2$ and $\vec{B}_2$. **(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) Electric field intensity vector in free space is given by $\vec{E} = E_0 \, \mathrm{Sin}(\omega t - \beta z)\, \hat{j}$. Obtain expressions for $\vec{D}, \vec{B}$ and $\vec{H}$ in free space. **(07 marks)**

3. a) (i) What is meant by Compton effect? **(02 marks)**

(ii) Write down the equation for Compton shift and name all the terms in the equation. **(03 marks)**

b) (i) An incident photon of frequency ν gets scattered through an angle ϕ from an electron at rest. Starting from Compton shift equation, show that the energy of scattered photon can be written as $E' = \dfrac{E}{1 + \dfrac{E}{m_0 c^2}(1 - \cos\phi)}$. **(06 marks)**

(ii) If the photon is scattered through an angle of 90°, show that the frequency of the scattered photon is given by $\nu' = \left(\frac{m_0c^2}{h\nu + m_0c^2}\right)\nu$. **(04 marks)**

c) A photon of energy 0.9 MeV is scattered through an angle of 120° by an electron at rest. Calculate the energy and the frequency of the scattered photon. **(10 marks)**

a) (i) What is meant by radioactivity? **(03 marks)**

(ii) Discuss briefly the properties of α, β and γ rays emitted in radioactivity. **(06 marks)**

b) A sealed capsule containing the radiopharmaceutical phosphorus-32 $\left({}^{32}_{15}\mathrm{P}\right)$, a β emitter, is implanted into a patient's tumor. The average kinetic energy of the β particles is 700 keV. The initial activity is 5.22 MBq. Assume that the β particles are completely absorbed within the tumor. The half-life of $\left({}^{32}_{15}\mathrm{P}\right)$ is 14.26 days. Note that 1 Bq represents a rate of radioactive decay equal to 1 disintegration per second.

(i) Find the decay constant of $\left({}^{32}_{15}\mathrm{P}\right)$. **(03 marks)**

(ii) How many nuclei are present initially? **(03 marks)**

(iii) How many nuclei will be remaining after 10 days? Hence find the number of nuclei, which decay within those 10 days. **(05 marks)**

(iv) Calculate the total energy released by β particles during a 10-day period in Joules. **(03 marks)**

(v) What would be the total energy absorbed during a 10-day period by patient's tumor? **(02 marks)**

5. A spaceship of length 50 m when it is stationary on Earth, leaves the Earth and travels at a constant velocity v away from the earth. An observer on the Earth measures the length of the traveling spaceship as 30 m. **(07 marks)**

a) Find the velocity v of the spaceship.

b) A small capsule is then released by the spaceship with a velocity of 0.75c with respect

to the spaceship. Find the velocity of the capsule with respect to the Earth;

(i) If the capsule is released in the same direction as the velocity of spaceship. **(06 marks)**

(ii) If the capsule is released in the opposite direction of motion of spaceship. **(06 marks)**

c) The spaceship is just returned to the Earth from a ten-year voyage according to the observer on the Earth. How many years have elapsed for the crew on the spaceship? **(06 marks)**

6. a) What are the different regions of Makowski space? Explain briefly. **(03 marks)**
Draw the worldline of you assuming you where at the origin at t = 0. **(03 marks)**

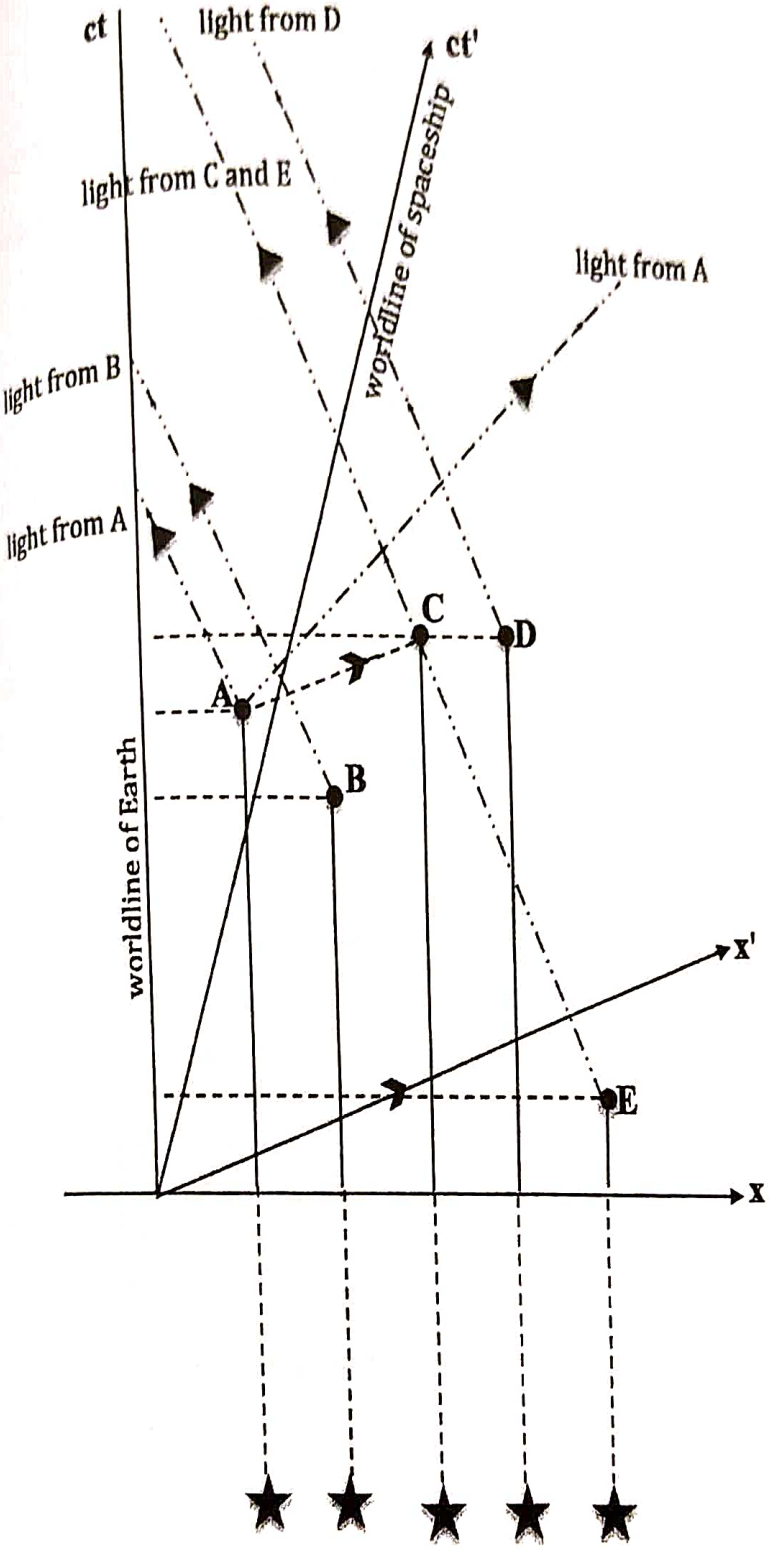
b) The following space-time diagram shows five stars which turn supernovae at space-time points A, B, C, D and E. These supernovae are observed by astronomers on the Earth and also by scientists aboard a fast moving spaceship. The trajectories of light from supernovae are shown in the space-time diagram below.

(i) In which chronological order do the five supernovae occur in the Earth frame of reference? **(04 marks)**

(ii) In which chronological order do the five supernovae occur in the spaceship frame of reference? **(05 marks)**

(iii) In which chronological order do the astronomers on Earth see the supernovae? **(05 marks)**

(iv) In which chronological order do the scientists on the spaceship see the supernovae? **(05 marks)**


ct
light from D
ct'
light from C and E
worldline of spaceship
light from A
light from B
light from A
C
D
A
B
worldline of Earth
x'
E
x

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