UNIVERSITY OF RUHUNA

B.Sc. General Degree Level II (Semester II) Examination – NOVEMBER/DECEMBER 2016

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)

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

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

$\mu_0 = 1.26 \times 10^{-8}$ 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 a.m.u = 1.66 x 10^{-27} kg

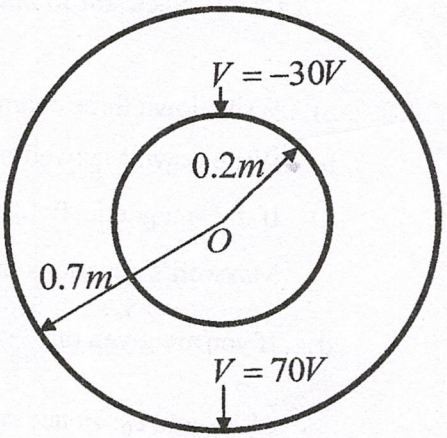
In spherical coordinates:

Laplace equation $\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial V}{\partial r}\right) + \frac{1}{r^2 sin\theta}\frac{\partial}{\partial \theta}\left(sin\theta \frac{\partial V}{\partial \theta}\right) + \frac{1}{r^2 sin\theta}\frac{\partial^2 V}{\partial \varphi^2} = 0$

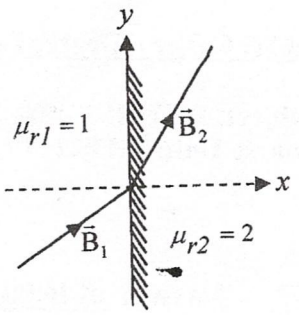
Del operator $\nabla = \frac{\partial}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial}{\partial \theta}\hat{\theta} + \frac{1}{r sin\theta}\frac{\partial}{\partial \varphi}\hat{\varphi}$

Part A

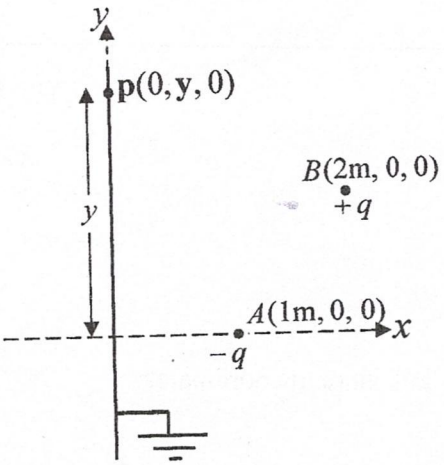
1. a) Figure shows two thin conducting concentric spherical shells placed in free space. The voltage of inner spherical shell of radius $0.2m$ is $-30V$ and the voltage of outer spherical shell of radius $0.7m$ is $70V$. Obtain expressions for V, $\vec{E}$ and $\vec{D}$ for the region between two shells, using the Laplace equation.



b) Following figure shows a current free interface between two magnetic media. If $\vec{B}_1 = \hat{\imath} + \hat{\jmath} + \hat{k}$, calculate $\vec{H}_1$, $\vec{H}_2$ and $\vec{B}_2$ using the given data in the diagram.



2. Two point charges of $-q$ and $+q$ are placed at points $A(1m, 0, 0)$ and $(2m, 1m, 0)$ respectively, near an infinitely large, grounded, conducting plate placed on yoz plane as shown in the figure.



a) Indicate the magnitude and location of image charge(s) required to replace the conducting plate.

b) Show that the electric field intensity at the point $P(0,\ y, 0)$ is given by

$$\vec{E} = \frac{q}{2\pi\varepsilon_0}\left(\frac{1}{(1+y^2)^{3/2}} - \frac{2}{(y^2-2y+5)^{3/2}}\right)\hat{\imath}.$$

c) If $q = 1C$, calculate the magnitudes of $\vec{E}$ at the points on the y axis when $y = 0$ and $y = 1m$.

d) What would be the total induced charge on the grounded plate?

(Note:-Need not to make a calculation)

3. a) Write down three characteristics of a free space.

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

c) If the magnetic field intensity vector in a free space is $\vec{H} = H_0 cos(\omega t - \beta x)\hat{k}$, use Maxwell's equations in electrodynamics to obtain expressions for $\vec{D}$ and $\vec{E}$.

d) If you are given that $\frac{\beta}{\omega} = \sqrt{\varepsilon_0\mu_0}$, show that the $|E|/|H|$ value depends only on the values of μ_0 and ε_0. Hence calculate the value of $|E|/|H|$.

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

Part B

4. a) (i) Write down the equation for the Compton shift. What are the independent and dependent quantities of the Compton shift?

(ii) What is Compton wavelength? Distinguish between Compton shift and Compton wavelength.

b) (i) Show that the kinetic energy of the recoil electron in Compton scattering is given by, $h\nu \frac{\frac{h\nu}{m_0c^2}(1-cos\emptyset)}{1+\frac{h\nu}{m_0c^2}(1-cos\emptyset)}$

(ii) Obtain an expression for the maximum kinetic energy of the recoil electron.

5. a) Write down de-Broglie equation. Derive an expression for de-Broglie wavelength of a matter particle of mass m in terms of its kinetic energy, E.

b) Calculate the de-Broglie wavelength for fast moving cricket ball of mass 1g and speed 1 cms^{-1}. Can this wavelength be observed? Discuss.

c) Calculate the wavelengths for a photon and electron of energy 10 eV each. Which one has a shorter wavelength? Explain the reasons for the difference.

6. a) (i) Discuss, briefly, Exothermic and Endothermic reactions.

(ii) Calculate the Q-value of the following decay processes and discuss the differences.

1) ${}^{57}_{27}Co \rightarrow {}^{57}_{26}Fe + {}^{0}_{1}e^{+} + {}^{0}_{0}\nu$ 2) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e^{-} + {}^{0}_{0}\overline{\nu}$

Masses in a.m.u

Co – 56.936294, C – 14.003242, Fe – 56.935396, N – 14.003074, e – 5.485 x 10^{-4}

b) A small building has become accidentally contaminated with radioactivity. The longest-lived material in the contaminated building is Strontium-90. ${}^{90}_{38}Sr$ has an atomic mass 89.9077 u and its half–life is 29.1 years. Assume that the building is initially contaminated with 5.0 kg of this substance, uniformly distributed throughout the building.

(i) How many nuclei are present at initially?

(ii) Find the decay constant of ${}^{90}_{38}Sr$.

(iii) Find the initial activity.

(iv) If the safe level of the building is defined as less than 10.0 decays/min, how long will the building be unsafe?

Part C

7. a) (i) What is meant by Simultaneity?

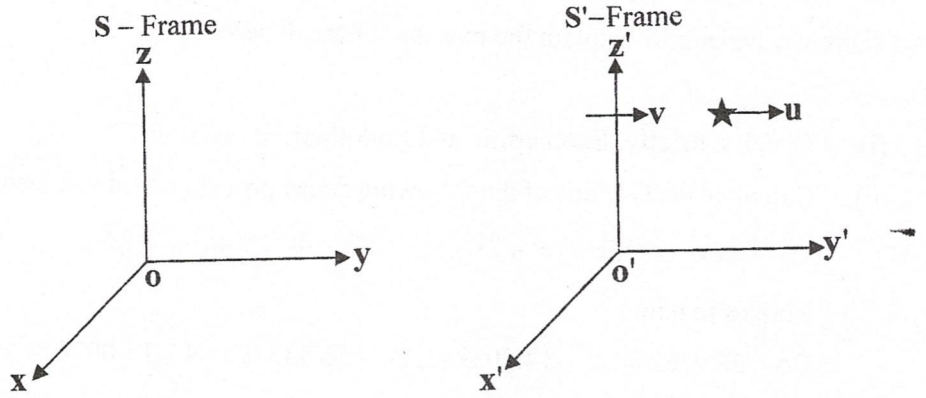
(ii) A bird at rest observes light from a firecracker, A, arrive at t = 3 μs which is exploding at x = 600 m and light from another firecracker, B, arrive at t = 5 μs which is exploding at x = 1200 m. Did the firecrackers explode simultaneously in the reference frame of the bird?

b) The electrons in the Australian Synchrotron travel at 0.999997c relative to the laboratory frame. The circumference of the Synchrotron beam path is 216 m.

(i) How long does it take for an electron to complete one cycle of the beam path in the laboratory reference frame?

(ii) How long does it take in the electron's reference frame?

8. Consider a particle travels in y- direction at velocity u with respect to inertial frame *S*. Frame *S′* moves at velocity v with respect to *S*.



a) Derive the velocity transformation equation for y - component.

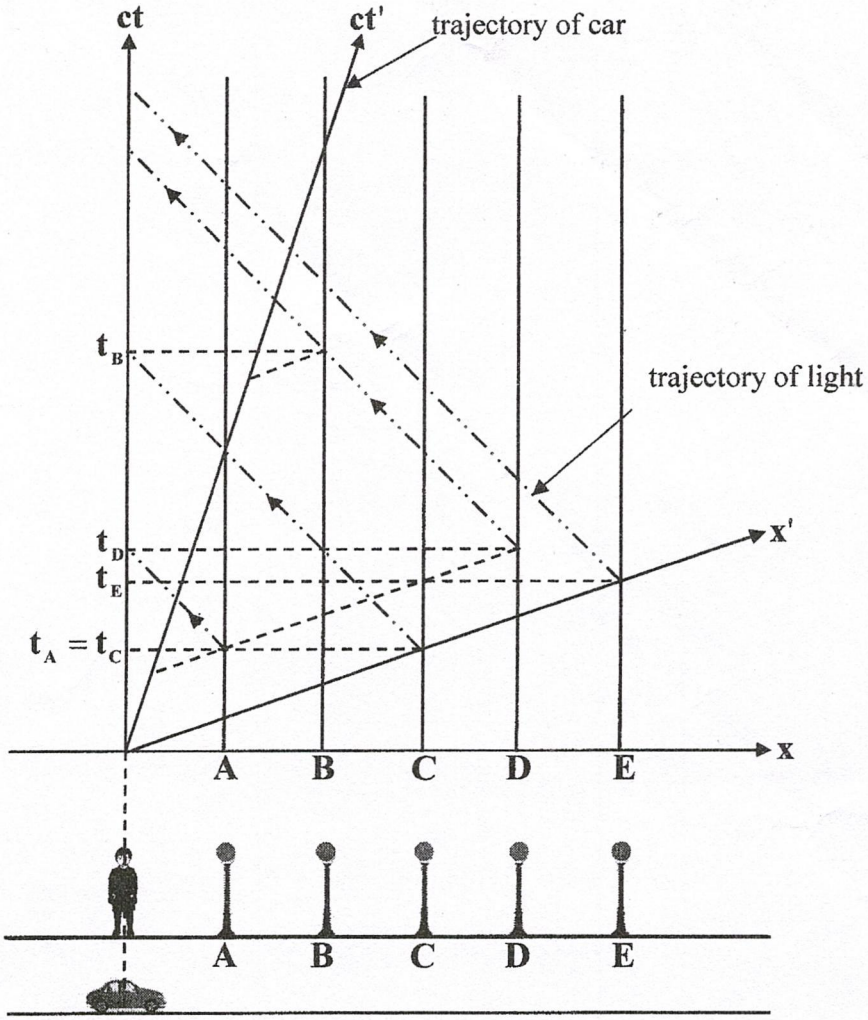
b) Hence write down the inverse velocity transformation for y - component.

c) A spaceship moves away from earth with speed v and fires a shuttlecraft in the forward direction at a speed v relative to the spaceship. The pilot of the shuttlecraft launches a probe in the forward direction at speed v relative to the shuttlecraft.

(i) Calculate the speed of the shuttlecraft relative to the earth.

(ii) Calculate the speed of the probe relative to the earth.

9. Five street lamps A, B, C, D and E are located on a straight line along the x – axis in a rest frame $(S \equiv (ct, x))$ with equal distance apart. They turn on at times t_A, t_B, t_C, t_D and t_E respectively, relative to the rest frame. This situations are indicated in the following space–time diagram.



a) What is the order in which the lamps turn on relative to the rest frame?

b) What is the order in which the light of the lamps reach the observer at x=o?

c) A car is $(S' \text{ frame} \equiv (ct', x'))$ moving at constant velocity relative to the rest frame. At $t' = t = 0$, it is at $x' = x = 0$. The space and time axes in the moving frame (ct′ and x′) of the car are tilted with respect to those of the rest frame as shown in the space-time diagram. What is the order in which the lamps turn on relative to the frame S′?

d) What is the order in which the light of the lamps reach the observer riding in the car?

e) When the light from street lamp D reaches the car where would be the car, between which street lights?

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