00439

The Open University of Sri Lanka
Faculty of Natural Sciences
B.Sc/ B. Ed Degree Programme

Department	**: Physics**
Level	**: 4**
Name of the Examination	**: Final Examination**
Course Title and - Code	**: Modern Physics PHU4300/PYU2160**
Academic Year	**: 2019/2020**
Date	**: 10.11.2020**
Time	**: 9.30am -11.30am**
Duration	**: Two hours (2hr)**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **(6)** questions in **(3)** pages.
3. Answer any **(4)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Draw fully labelled diagrams where necessary
6. Involvement in any activity that is considered as an exam offense will lead to punishment
7. Use blue or black ink to answer the questions.
8. Clearly state your index number in your answer script

You may assume that, c=3x10^8 ms^{-1}, h= 6.63x10^{-34} Js, 1eV=1.6x10^{-19}J, π=3.14, mass of the electron=9.1x10^{-31} kg, mass of the proton=1.67x10^{-27} kg, R_H= 1.097x10^7 m^{-1}, e=1.6x10^{-19} C, Wien's constant= 2.8978 x10^{-3}mK

1. The Planck distribution function for blackbody radiation is,

$$I(\lambda) = \frac{2\pi hc^2}{\lambda^5\left[e^{\left(hc/\lambda kT\right)} - 1\right]}$$

Where h is Planck's constant, c is the speed of light, k is Boltzmann's constant, T is the absolute temperature of the blackbody, and λ is wavelength.
The Rayleigh radiation law is expressed as,

$$I(\lambda) = \frac{2\pi ckT}{\lambda^4}$$

(a) Sketch both laws as a function of wavelength for a fixed temperature. **(6 marks)**

(b) Show that the Planck law reduces to Rayleigh radiation law at very large wavelengths $\left[\lambda \gg \frac{hc}{kT}\right]$.

(Hint: Taylor series expansion $e^x = 1 + x + \frac{x^2}{2!} + \cdots$) **(6 marks)**

(c) On a single diagram, sketch the Planck law for the intensity distribution $I(\lambda)$ versus λ for two temperatures T_1 and T_2 such that $T_1<T_2$. State the Wien displacement law and with reference to your diagram explain what it means.

(7 marks)

(d) Find the peak wavelength of the blackbody radiation emitted by a red hot steel ball with temperature 1000K. In which region of spectrum this radiation belongs to?

(6 marks)

2. (A) Discuss the differences among (a) the plum pudding model of the atom (b) the Rutherford model of the atom. **(6 marks)**

(B) An electron is in a Bohr orbit with a principal quantum number n_i=3, and then jumps to a final orbit for the final value n_f=1, find

(a) the radius of the nth orbit **(4 marks)**

(b) the speed of the electron in the nth orbit **(3 marks)**

(c) the energy of the electron in the nth orbit **(4 marks)**

(d) the wavelength of the spectral line associated with the transition from the n_i=3 state to the final n_f=1 state. **(4 marks)**

(e) Explain what is meant by the Balmer series of Hydrogen. **(4 marks)**

3.

(a) Define the terms "eigenfunction" and "eigenvalue" **(2marks)**

(b) The Schrodinger equation for a particle moving in one-dimensional system is given below.

$$\frac{d^2}{dx^2}\psi + \frac{2m}{\hbar^2}[E - V(x)]\psi = 0$$

Identify all terms appearing in the above equation, stating the quantities represented by the symbols. **(2marks)**

(c) Convert the above equation into the form of $\hat{H}\psi = E\psi$ and hence identify the corresponding Hamiltonian operator, $\hat{H}$. **(6marks)**

(d) Show that the function,

$$\psi(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right) \quad n = 1,2,3 \ldots\ldots$$ is an eigenfunction of the above Hamiltonian operator and deduce an expression for the energy of the particle when V(x)=0 in the range of $0 < |x| < L$. **(7marks)**

(e) An electron is confined to a linear cavity of length 0.1nm, in a crystal where the potential is infinite outside the cavity and is zero inside the cavity. Calculate the energy of the electron in the ground state and the wavelength of radiation necessary to excite the electron from the ground state to the first excited state. **(8marks)**

4. (a) State the Einstein's postulates of special relativity. **(6 marks)**

(b) What is meant by the "Length contraction"? **(3 marks)**

(c) Write down the Lorentz transformations with usual notation. **(5 marks)**

(d) How fast must a 4.57m long car move in order to fit into a 3.05m long garage? **(5 marks)**

(e) A women on the earth observes a firecracker explode 10.0m in front of her when her clock reads 5.00s. An astronaut in a rocket ship who passes the women on earth at t=0, at a speed of 0.40c, find coordinates for this event in the rocket. **(6marks)**

5.

(a) Consider S and S$'$ are two observers. Observer S$'$ is moving at uniform velocity v in the positive X- direction relative to S. An object is moving with velocity component U_x' in the frame of reference S$'$, and U_x is the corresponding velocity component according to S, and c is the velocity of light. Using the Lorentz transformations equations obtain an expression for U_x. **(6marks)**

(b) A rocket travelling at speed 0.5c relative to the earth shoots forward bullets traveling at speed 0.6c relative to the rocket. What is the bullet's speed relative to the earth? **(5marks)**

(c) What do you meant by the Red shift? **(4 marks)**

(d) If an observer directly moving away from a light source of frequency f_0 with a relative velocity, v, write an expression for the frequency f measured by the observer. **(5 marks)**

(e) It is found that the light from a nearby star is blue shifted by 1%; that is, $f_{observer}=1.01\,f_{source}$. Is the star receding or approaching, and how fast is it travelling? **(5 marks)**

6.

(a) Without deriving any equation state the relativistic expression of mass-velocity relation for a particle of mass m_0, write down the relativistic expressions for its momentum, p and its total energy, E. Hence or otherwise, prove that $E^2 = p^2c^2 + m_o^2c^4$ **(14 marks)**

(b) An electron is moving at $0.6c$. What is its energy E? At this speed, what fraction of its energy is rest energy? **(5 marks)**

(c) A particle, M at rest decays in to two fragments of known masses $m_1=0.5\text{GeV}/c^2$ and $m_2 = 1\text{GeV}/c^2$, whose momenta are measured to be $p_1=2\text{GeV}/c$ along the positive x axis and $p_2=1.5\text{GeV}/c$ along the negative x axis. Find the speeds of the fragments and unknown mass M. **(6 marks)**