KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE

SPH 202: MODERN PHYSICS

DATE: Wednesday 28th March, 2012 **TIME:** 2.00 p.m. – 4.00 p.m.

Instructions:

This examination paper contains five questions. Question one carries 30 Marks and the rest carry 20 Marks each.

Answer Question one and any other two questions.

Useful Information:

atomic mass unit u $\simeq$ 931MeV
Bohr radius for the first orbit in hydrogen $\simeq$ 0.0529 nm
Boltzmann constant K $\simeq 1.38 \times 10^{-23}$JK^{-1}
Compton wavelength $\lambda_c \simeq 2.43 \times 10^{-12}$ m
constant in Wien's displacement law $\simeq 2898\mu$mK
electron charge $e \simeq 1.602 \times 10^{-19}$ C
electronvolt, 1 eV $\simeq 1.602 \times 10^{-19}$ J
muon life-time $\simeq 2.2\mu s$
Planck's constant $h \simeq 6.626 \times 10^{-34}$ J s
reduced Planck's constant $\hbar \simeq 6.582 \times 10^{-22}$ MeV s
$hc \simeq$ 12.4 keVÅ
restmass of the electron $\simeq 9.1 \times 10^{-31}$ kg $\simeq$ 0.511MeV/c^2
restmass of the neutron $\simeq 1.674 \times 10^{-27}$ kg $\simeq$ 1.00876u $\simeq$ 940MeV/c^2
restmass of the proton $\simeq 1.672 \times 10^{-27}$ kg $\simeq$ 1.00728u $\simeq$ 938MeV/c^2
speed of light $c \simeq 3 \times 10^8$ m/s
Stefan-Boltzmann constant $\sigma \simeq 5.67 \times 10^{-8}$Wm^{-2}K^{-4}

Question 1:

(a) When in Michelson-Morley experiment no fringe was observed. it was concluded that the speed of light in free space is the same regardless of any motion of source or observer. What was the reason to arrive at this conclusion? Is this conclusion one of the postulates of the special theory of relativity? Which is the other postulate?

(5 Marks)

(b) Assuming the surface temperature of the sun to be 5700^0K, use Stefan's law to determine the mass lost per second to radiation by sun.
(Given the sun's diameter = 1.4×10^9m).

(5 Marks)

(c) Calculate the de Broglie wavelength of a ball of mass 200g moving with a speed 20m/s. Comment on the result.

(5 Marks)

(d) The threshold wavelength for photoelectric emission from the surface of tungsten is 230nm. What wavelength of light must beused in order to emitt photoelectrons with maximum kinetic energy of 1.5eV?

(5 Marks)

(e) In the Bohr model of hydrogen atom the speed of the electron in its orbit is given as.

$$\mathrm{v} = \frac{\mathrm{e}}{\sqrt{4\pi\epsilon_0 mr}} .$$

Show that the magnitude of the potential energy of the electron is two times its kinetic energy.

(5 Marks)

(f) Briefly explain the term **Q-value** of a nuclear reaction. Two α- particles each of energy 13.2 MeV are formed when ^{6}Li is bombarded with 4MeV deuterons. Calculate the Q-value for this reaction.

(5 Marks)

Question 2:

(a) Write the relativistic formula for the kinetic energy of a body of rest mass m_0 and then show that it reduces to the ordinary mechanics formula when the speed of the body is small compared with the velocity of light.

(5 Marks)

(b) μ mesons are created by the cosmic ray particles at an altitude of about 8500 m from the sea level. Their mean lifetime measured at rest is 2×10^{-6} s. In its lifetime it can travel a distance of only 600m with its speed of 0.998c. But these μ mesons reach the earth in abundance. Explain this meson paradox from the frame of reference of meson by making use of Lorentz-Fitzgerald contraction.

(6 Marks)

(c) Two spaceships are moving in the same direction with a relative speed of 0.7c. If the speed of one of the spaceships (slower one) is 0.8c as measured by an observer on earth, find the speed of the other spaceship with respect to the observer on earth.

(5 Marks)

(d) Find the momentum of a 1 MeV electron.

(4 Marks)

Question 3:
(a) Briefly explain the Franck - Hertz experiment. Your explanation should include the following,

- the aim of the experiment,
- a sketch of the experimental set-up,
- the observations made, and,
- the interpretation of the results.

(10 Marks)

(b) Hydrogen atom emits a photon of wavelength $\lambda = 4890\text{Å}$ in a transition to a state of excitation energy 10.19 eV.

(i) Calculate the binding energy of the initial state, and hence,

(ii) the principle quantum numbers n_i and n_f for the initial and final states respectively.

(10 Marks)

Question 4:

(a) What is the difference between the Doppler red-shift and graviational red-shift? What are their implications? Consider photons of frequency ν emitted by a star of mass M and radius R.

(i) Find an expression for the potential energy and hence the total energy of a photon at the surface of the star.

(ii) If the frequency of the photons far away from the star is ν', find an expression for the relative change in frequency of the photon.

(iii) A photon of wavelength $\lambda = 500$nm is emitted by the Sun. Calculate the energy of the photon in eV and the change in energy due to gravitational red-shift. Comment on your results.

(10 Marks)

(b) State Heisenberg's uncertainty principle.

(i) Show that for a particle moving in a circle,

$$\Delta L \, \Delta\theta \geq \frac{\mathrm{h}}{4\pi}$$

where ΔL and $\Delta\theta$ are the uncertainties in the angular momentum and angle respectively.

(ii) Apply the relation in **(i)** for a state of fixed angular momentum, e.g. an electron in a Bohr orbit and comment on the result.

(10 Marks)

Question 5:

(a) Define the mean lifetime of a radioisotope and find the relationship between its half life $T_{1/2}$ and its mean lifetime.

(5 Marks)

(b) The half life of sodium isotope $_{11}N^{24}$ is 15 hours. How long does it take for 75 percent of a sample of this isotope to decay?

(5 Marks)

(c) Define nuclear fusion. Explain how the energy is released in this process.

(6 Marks)

(d) 'Greater is the binding energy per nucleon of a nucleus, greater is the stability of the nucleus.' Explain this statement.

(4 Marks)