MACHAKOS UNIVERSITY

University Examinations 2021/2022

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SUPPLEMENTARY/SPECIAL EXAMINATION FOR
BACHELOR OF SCIENCE (MATHEMATICS)
BACHELOR SCIENCE (TELECOMMUNICATION & INFORMATION TECHLOGY),
BACHELOR SCIENCE (APPLIED PHYSICS AND TECHNOLOLOGY,
BACHELOR OF SCIENCE (SPECIAL NEEDS EDUCATION)
BACHELOR EDUCATION (SCIENCE)
SPH 202: MODERN PHYSICS

DATE:17/03/2022 **TIME: 8:30-10:30 AM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

Useful information

Speed of light in free space c =2.998 x $10^8\ m/s$, Mass of an electron 9.11x $10^{-31}kg$, plank constant 6.626x$10^{-34}j/s$, 1eV = 1.67 x $10^{-19}j$, Boltzmann constant= 8.617332 × 10^{-5} eV/K, Planck's constant h = 6.62606957 × 10^{-34} J ·s, Electron mass 9.1093829 × $10^{-31}kg$, Permittivity of free space ε_o = 8.854 x $10^{-12}12C^2$/N. m^2, h-bar $\hbar=\frac{h}{2\pi}$, Electron charge e 1.602 x $10^{-19}\ C$,

Appendix 1; contains work functions of different metals. It also contains more constanst.

Question 1

a) Define a blackbody (2 marks)

b) Draw an electromagnetic spectrum and use it to explain why a blackbody emits radiation which is invisible, then reddish, then yellowish white to whitish as its temperature is increased 4 marks

c) Define photoelectric effect (2 marks

d) Explain what is meant by gravitational red shift of spectral lines (3 marks)

e) Describe
   i) Redshift of spectral lines
   ii) Gravitational red shift
   iii) Quarsar
   iv) Blackhole 5 marks

f) Show that velocity of an electron orbiting the hydrogen atom is related to its mass *m* and orbit radius *r* by 4 marks

g) Draw de Broglie wavelengths for for n=2, n=2.5, n=3 and n=4 4 marks

h) A hydrogen atom is the simplest of all atoms with one electron orbiting its nuclear. Calculate
   i) the Bohr radius a_0 of an electron orbiting hydrogen atom (2 marks)
   ii) circumference of the electron orbit (1 mark)
   iii) de Broglie wavelength of the electron (2 marks)
   v) comment on the answer ii) and iii) (1 mark)

Question 2

a) The work done *W* on a relativistic particle at rest, by a force *F* which is not constant, through a distance *s* is given by KE =$\int_0^s Fds$. Show that
   i. the correct relativistic formula for kinetic energy is $KE = \gamma mc^2 - mc^2$ (if all calculus is shown 8 Marks else 5 marks)
   ii. the total energy $E = \gamma mc^2 = mc^2 + KE$ (2 marks)
   iii. rest energy $E_0 = mc^2$ (1 mark)s
   iv. total energy $E = mc^2(1 - v^2/c^2)^{-1/2}$ (1 mark)s

b) A stationary body of mass 2.0 kg explodes into 4 fragments of mass 0.02kg, 0.34 kg and 0.12 kg that move apart at speeds of 0.6c, 0.9c and 0.95c respectively. If the speed of the fourth fragment is 0.4c, find its.
   i. Mass (5 marks)
   ii. Total energy (3 marks)

Question 3

a) Derive an equation for relativistic Newton second law (3 marks)

b) Show that energy and momentum are related by $E^2 = (mc^2)^2 + p^2c^2$ (4 marks)

c) A relativistic particle of mass *m* moving with a velocity *v* is acted upon by a constant force F which is parallel to *v*.
   i. Show that its acceleration is given by

$$a = \frac{F}{m}\left(1 - {}^{v^2}/_{c^2}\right)^{3/2}$$

(9 marks)

   ii. An electron in a free space is accelerated at 3.24 x $10^{12} m/s^2$ by a force of 2.5 x $10^{24}\ N$. Calculate its speed (4 marks)

Question 4

a) A woman leaves the earth in a spacecraft that makes a round trip to the nearest star, 4 light-years distant, at a speed of 0.9*c*. How much younger is she upon her return than her twin sister who remained behind? (6 marks)

b) Figure 2 shows behaviour of some material when it's heated from 2000 K to 4000 K. Explain

i) why and

ii) how the colour of radiation emitted changes with increase in temperature (4 marks)

c) Show that the total energy of the hydrogen atom is given by $E = -k\frac{e^2}{2r}$ where r- is the radius of the orbit, e is charge of an electron/proton and k is Boltzmann constant. (6 marks)

d) Show that kinetic energy can be written in terms of linear momentum as $KE = \frac{p^2}{2m}$ where *p*- linear momentum of a particle of mass *m* (4 marks)

Question 5

a) The set-up shown in figure 3 shows how photoelectric effect was studied.

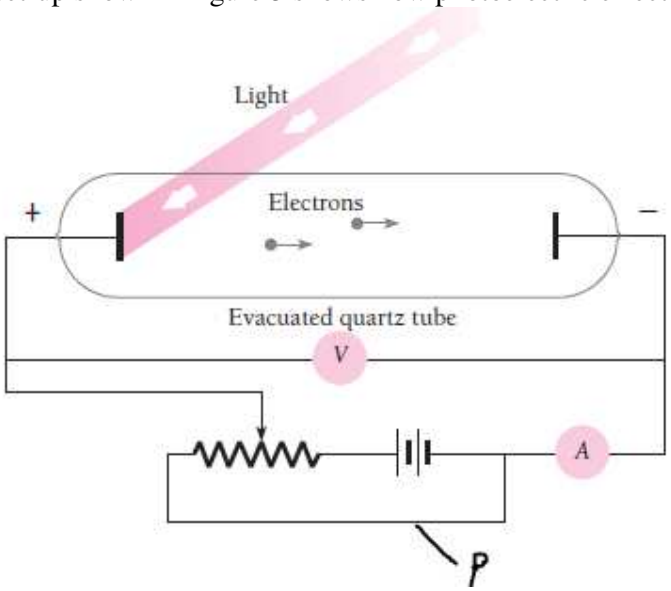

Figure 3

i) Explain how the set-up operates ((2 marks))

ii) Explain how electrons generated manage to result to measured current yet they are negative directed to the negative cathode. ((2 marks))

iii) Re-draw the diagram show all currents when

I. Light intensity is zero (2 marks)

II. Light intensity of sufficient intensity to cause photoelectric effect is present (2 marks)

iv) What is the significance of the loop labelled *p,* in other words, how will it affect the set-up, in-case its remove (3 marks)

v) State the effect on measured current of

I. Bright light as compared to dim light (2 marks)

II. Blue light as compared to red light (2 marks)

b) Blue light of wavelength 450 nm is directed at a caesium Cs surface. Calculate the maximum KE of the photoelectrons emitted by the surface. (5 marks)

Appendix 1; Work functions of some materials

Table 2.1 Photoelectric Work Functions

Metal	Symbol	Work Function, eV
Cesium	Cs	1.9
Potassium	K	2.2
Sodium	Na	2.3
Lithium	Li	2.5
Calcium	Ca	3.2
Copper	Cu	4.7
Silver	Ag	4.7
Platinum	Pt	6.4

Constants

Atomic mass unit u= 1.66 x10^{-27}Kg, Avogadro's number 6.022 x 10^{23}particles/mol, boltzmann's constant k_B = 1.38x10^{-23}J/K, Deutron mass m_d= 3.343x10^{-27}Kg,electron mass m_e= 9.109x10^{-31}Kg, electron volt eV=1.602 x10^{-19}J, charge e= 1.602x10^{-19}C, Gas constant R= 8.314J/K.mol, Gravitational constant G= 6.672x10^{-11}N.m^2/kg, neutron mass m_n=1.674x10^{-27}Kg, Permeability of free space $\mu_o = 4\pi\ x\ 10^{-7} T.m/A$, Permetivity of free space $\epsilon_o = 8.854\ x\ 10^{-12} C^2/N.m^2$. Plank's Constant $h = 6.626\ x\ 10^{-34} J.s$, ħ=1.054 x$10^{-34} J.s$, Proton mass $m_p = 1.672\ x10^{-27} Kg$, Rydberg constant $R_H = 1.097\ X\ 10^7 m^{-1}$, speed od light in a vacuum c = 2.997 x $\frac{10^8 m}{s}$, One light year(1Ly)is the diatance travelled by light in one year which is 9.4607 x 10^{12} Km