



MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION (SCIENCE)

SPH 202: MODERN PHYSICS

DATE: 9/5/2019

TIME: 2.00-4.00 PM

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 $c = 2.998 \times 10^8 \text{ m/s}$, Mass of an electron $9.11 \times 10^{-31} \text{ kg}$, plank constant $6.626 \times 10^{-34} \text{ J}\cdot\text{s}$, $1\text{eV} = 1.67 \times 10^{-19} \text{ J}$, Boltzmann constant $= 8.617332 \times 10^{-5} \text{ eV/K}$, Planck's constant $h = 6.62606957 \times 10^{-34} \text{ J}\cdot\text{s}$, Electron mass $9.1093829 \times 10^{-31} \text{ kg}$, Permittivity of free space $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$, $\hbar = \frac{h}{2\pi}$, Electron charge $e = 1.602 \times 10^{-19} \text{ C}$,

Appendix 1; contains workfunctions of some materials.

Appendix 11; More constants can also be found here.

QUESTION ONE (30 MARKS)

- 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
- Redshift of spectral lines
 - Gravitational red shift
 - Quasar
 - 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)

$$v = \frac{c}{\sqrt{4\pi\epsilon_0 m r}}$$

- g) With a well drawn diagrams show the de Broglie wavelengths of a standing wave model of the atom for $n=1$, $n=2$, $n=2.5$, $n=3$ and $n=4$ (4 marks)
- h) A hydrogen atom is the simplest of all atoms with one electron orbiting its nuclear. Calculate
- the Bohr radius a_0 of an electron orbiting hydrogen atom (2 marks)
 - circumference of the electron orbit (1 mark)
 - de Broglie wavelength of the electron (2 marks)
 - comment on the answer ii) and iii) (1 mark)

QUESTION TWO (20 MARKS)

- 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 $KE = \int_0^s F ds$. Show that
- the correct relativistic formula for kinetic energy is $KE = \gamma mc^2 - mc^2$
(if all calculus is shown 8 Marks) else 5 Marks)
 - the total energy $E = \gamma mc^2 = mc^2 + KE$ (2 marks)
 - rest energy $E_0 = mc^2$ (1 mark)
 - total energy $E = mc^2(1 - v^2/c^2)^{-1/2}$ (1 mark)

- 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.
- Mass (5 marks)
 - Total energy (3 marks)

QUESTION THREE (20 MARKS)

- Derive an equation for relativistic Newton second law (3 marks)
- Show that energy and momentum are related by $E^2 = (mc^2)^2 + p^2c^2$ (4 marks)
- A relativistic particle of mass m moving with a velocity v is acted upon by a constant force F which is parallel to v .
 - Show that its acceleration is given by

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

(if all maths steps are shown, 9 marks) else 6 marks))

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

QUESTION FOUR (20 MARKS)

- 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 $0.9c$. How much younger is she upon her return than her twin sister who remained behind? (6 marks)
- Figure 2 shows behaviour of some material when its heated from 2000 K to 4000 K. Explain
 - why and
 - how the colour of radiation emitted changes with increase in temperature
 (4 marks)

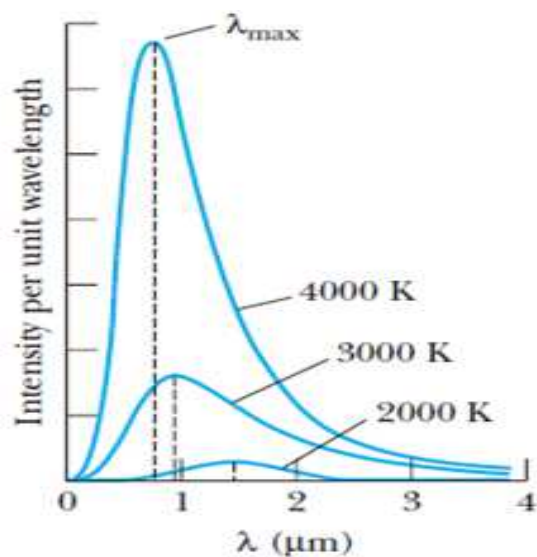


Figure 2

- a) 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)
- c) 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 FIVE (20 MARKS)

- a) The set-up shown in figure 1 shows how photoelectric effect was studied.

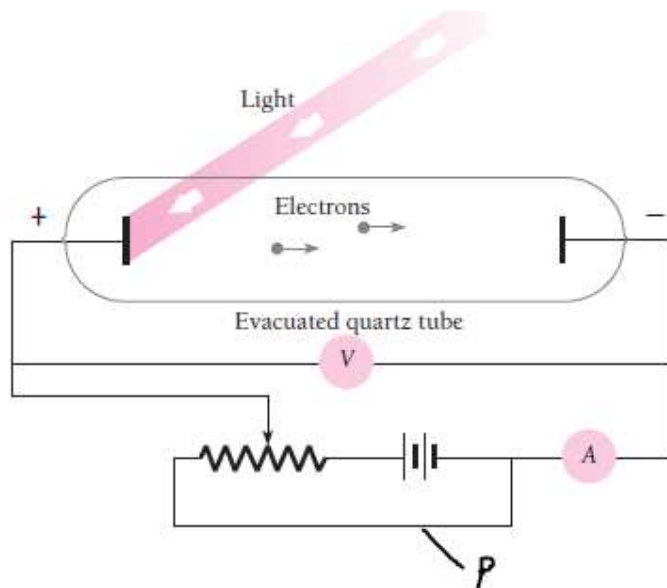


Figure 1

- 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 cesium 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

Appendix 11;

Atomic mass unit $u = 1.66 \times 10^{-27} \text{Kg}$, Avogadro's number 6.022×10^{23} particles/mol, boltzmann's constant $k_B = 1.38 \times 10^{-23} \text{J/K}$, Deuteron mass $m_d = 3.343 \times 10^{-27} \text{Kg}$, electron mass $m_e = 9.109 \times 10^{-31} \text{Kg}$, electron volt $\text{eV} = 1.602 \times 10^{-19} \text{J}$, charge $e = 1.602 \times 10^{-19} \text{C}$, Gas constant $R = 8.314 \text{J/K.mol}$, Gravitational constant $G = 6.672 \times 10^{-11} \text{N.m}^2/\text{kg}$, neutron mass $m_n = 1.674 \times 10^{-27} \text{Kg}$, Permeability of free space $\mu_0 = 4\pi \times 10^{-7} \text{T.m/A}$, Permetivity of free space $\epsilon_0 = 8.854 \times 10^{-12} \text{C}^2/\text{N.m}^2$. Plank's Constant $h = 6.626 \times 10^{-34} \text{J.s}$, $\hbar = 1.054 \times 10^{-34} \text{J.s}$, Proton mass $m_p = 1.672 \times 10^{-27} \text{Kg}$, Rydberg constant $R_H = 1.097 \times 10^7 \text{m}^{-1}$, speed of light in a vacuum $c = 2.997 \times \frac{10^8 \text{m}}{\text{s}}$, One light year(1Ly) is the distance travelled by light in one year which is $9.4607 \times 10^{12} \text{ Km}$