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DEPARTMENT OF PHYSICS

2003/2004 HARMATTAN SEMESTER EXAMINATION JUNE 2004

PHY 203: ELEMENTARY MODERN PHYSICS I TIME: 2 1/2 HOURS

INSTRUCTION: ANSWER QUESTION NO.1, AND ANY OTHER THREE QUESTIONS.

WRITE YOUR DEPARTMENT CLEARLY ON THE ANSWER BOOKLET

Useful Constants:

$1\mathring{A} = 10^{-10}$ m
h = Planck's constant = 6.63×10^{-34} J.s
k = Boltzman's constant = 1.38×10^{-23} JK^{-1}
C = Speed of EM waves in vacuo = 3.0×10^{8} ms^{-1}
m_o = Mass of the electron = 9.1×10^{-31} kg
W = Wien's constant = 2.898×10^{-3} m.K
σ = Stefan's constant = 5.670×10^{-8} Wm^{-2} K^{-4}

1(a) What are electromagnetic waves? Name any two types.
(b) What is the frequency of an x-ray photon whose momentum is 1.1×10^{-23} kgm/s?
(c) What is a blackbody ?
(d) State Stefan's law.
(e) A water pipe is made of thin copper and has a diameter of 3.0cm. It carries water at a temperature of 30°C above the surrounding air. Estimate the amount of energy lost by radiation per second along a 1m length of pipe if the surrounding air has a temperature of 18°C.
(f) Explain the process of pair production.
(g) A positron collides head on with an electron and both are annihilated. Each particle has a kinetic energy of 1MeV. Find the wavelength of the resulting photon.
(h) What is a blackhole?
(i) State the correspondence principle.
(j) Explain the term *ultraviolet catastrophe*

(40 Marks)

2(a) Given that Planck's blackbody radiation formula is

$$E_\lambda d\lambda = 8\pi hCd\lambda / \lambda^5(\exp(hc/\lambda kT) - 1)$$

where the symbols have their usual meanings. Derive Wien's displacement law.

(b) The solar radiation striking the Earth has an intensity of $1.4kW/m^2$. A black metal plate is placed so that the sunlight strikes its surface at 90°. The temperature of the surrounding air is 20°C.

(i) Explain why the temperature of the piece of metal rises to a constant value.

(ii) Calculate the value of this constant temperature.

(c) Describe the operating principle of a solar air dryer. (20 Marks)

3(a) Draw and label the Coolidge type x-ray tube.

(b)(i) Describe the operation of the x-ray tube, stating how the intensity and the penetrating power of the x-rays could be varied.

(ii) Draw the spectral curves for x-rays from a molybdenum target tube, operated at a low voltage (10kv) and at a high voltage (40kv). Explain the features of each curve.

(c) If the potential difference across an x-ray tube is $1.5 \times 10^5 V$, and the current is $1.0 \times 10^{-3} A$, find

(i) the number of electrons crossing the tube per second, and

(ii) the kinetic energy gained by an electron crossing the tube without any collision.

(20 Marks)

4(a)(i) Explain *photoelectric effect.*

(ii) What is the work function of a metal?

(iii) Why is there a maximum wavelength above which the photoelectric effect is not possible?

(b)(i) Why is it impossible for a photon to give up all its energy and momentum to a free electron?

(ii) When a copper surface is illuminated by the radiation of wavelength $\lambda = 2537\text{Å}$ from a mercury arc, the value of the stopping potential is found to be 0.24V. What is the threshold frequency for the copper surface?

$eV_s = hf - hf_0 = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right] = 1.969 \times 10^{-25}\left[\frac{1}{2537 \times 10^{-10}} - \frac{1}{\lambda_0}\right]$

$eV_s = h\left(\frac{c}{\lambda} - f_0\right) \Rightarrow -hf_0 = eV_s - h\frac{c}{\lambda} \Rightarrow hf_0 = -eV_s + \frac{hc}{\lambda}$

$f_0 = \frac{c}{\lambda} - \frac{eV_s}{h} \Rightarrow f_0 = \frac{c}{\lambda} - \frac{eV_s}{h}$