THE OPEN UNIVERSITY OF SRI LANKA

DEPARTMENT OF PHYSICS

BACHELOR OF SCIENCE DEGREE PROGRAMME -2010/2011

PYU2160 – MODERN PHYSICS - LEVEL 04 - FINAL EXAMINATION

TIME: TWO HOURS (2 hrs) **ANSWER FOUR QUESTIONS ONLY**

Date: 16.12.2010 Time: 1.00 pm – 3.00 pm

You may assume that, mass of electron $m_e = 9.1 \times 10^{-31}$ kg, $h = 6.63 \times 10^{-34}$ J s, $\pi = 3.14$, $\hbar = 1.05 \times 10^{-34}$ J s, $c = 3 \times 10^{8}$ m s^{-1}, 1 eV = 1.6×10^{-19} J.

1) Experiments on the photoelectric effect show that the kinetic energy of photoelectrons released depends upon the frequency of the incident light and not on its intensity, and below a certain frequency cannot release photoelectron. How do these conclusions support a particle theory but not a wave theory of light?

   In a standard photoelectric experiment a target is irradiated with ultraviolet (UV) light at wavelength 2800Å at certain intensity and electrons are emitted with a maximum kinetic energy of 15.0×10^{-20} J.

   (i) For the same target, the wavelength of light is halved to 1400Å, and the intensity is kept the same. Does the maximum kinetic energy of the emitted electrons double? Briefly explain your reasoning.

   (ii) The wavelength of light is now kept at 2800 Å, and the intensity is doubled. What is the maximum kinetic energy of the emitted electrons? Explain briefly.

   (iii) If the wavelength of light is changed to 4000Å, it is found that there are no electrons emitted, no matter what the intensity. With suitable calculation explain why this situation occurs.

2) State the de Broglie relation for the momentum p of a particle in terms of its associated wavelength λ.

   A parallel beam of violet light of wavelength 4500Å and intensity 700 W m^{-2} is incident normally on a surface.

   (i) Calculate the energy of a photon of violet light and the number of photons incident per second on of the surface

   (ii) Calculate the momentum of a photon of the violet light

   (iii) Use your answer to (i) and (ii) to calculate the change in momentum of photons incident on 1.0×10^{-4} m^2 of the surface in one second. Assume that the photons are absorbed by the surface.

3) 1-D time-independent Schrödinger equation for an electron with energy E incident on a potential step with height $U_0 > E$ can be described by

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2}+U(x)\psi(x)=E\psi(x),$$

with potential $U(x) = 0$ for $x < 0$ and $U(x) = U_0$ for $x \geq 0$

(i) If the wave function in the region $x < 0$ is $\psi_1(x)=Ae^{ikx}+Be^{-ikx}$, using the 1-D time-independent Schrödinger equation determine the value of k.

(ii) If the wave function in the region $x \geq 0$ is $\psi_2(x)=Ce^{-i\mu x}$, using the 1-D time-independent Schrödinger equation determine the value of μ.

(iii) Write down the boundary conditions on the wave function at $x = 0$

(iv) Using the boundary conditions mentioned in (iii), show that

$$A=\frac{1}{2}\frac{k+i\mu}{k}C \qquad \text{and} \qquad B=\frac{1}{2}\frac{k-i\mu}{k}C$$

(v) Using the result of (iv), show that the wave function may be written as

$$\psi(x)=C\left\{\cos kx-\frac{\mu}{k}\sin kx\right\} \text{ for } x<0, \text{ and } \psi(x)=Ce^{-\mu x} \text{ for } x\geq 0$$

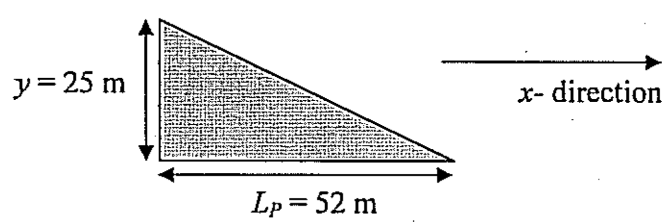
4) Write down the Lorentz transformation equations. Using these equations derive expressions for

(i) the length contraction,

(ii) time dilation and

(iii) velocity transformation in x-direction.

A spacecraft in the form of a triangle flies by an astronaut with a speed of $0.95c$ along the x- direction. According to an observer on the spacecraft (astronaut), the distances L_P and y are measured as 52 m and 25 m respectively as shown in the figure.



What are the dimensions of the spacecraft as measured by the Earth observer when the spacecraft is in motion along the x-direction?

5)

(i) Using the relativistic expression for mass show that the kinetic energy, K, of a particle is given by $K = mc^2 - m_0c^2$, where m and m_0 are the relativistic mass and rest mass of the particle respectively and c is the velocity of light.

(ii) If P and E are the momentum and energy of the particle show that

$$E^2 = P^2c^2 + m_0^2c^4.$$

(iii) A particle of rest mass m moving along x-axis with velocity v collides with a particle of rest mass $\frac{m}{2}$ moving along the x-axis with velocity $-v$. If the two particles join together, find the rest mass of the resulting particle. Hence, show that in the classical limit this value (mass of the resulting particle) will reduce to $\frac{3m}{2}$.

6) Briefly describe the red shift related to the Doppler effects in light.

Derive the relativistic Doppler formula for the longitudinal Doppler shift of the frequency. Hence deduce a formula that can be express the longitudinal Doppler shift in terms of wavelength.

A spectral line of wavelength 4000 Å in the spectrum of light from a star is found to be displaced from its normal position towards the red end of the spectrum by an amount equivalent to 1 Å. What velocity of the star in the line of light would account for this?

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