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GAILLIMH

NATIONAL UNIVERSITY OF IRELAND
GALWAY

SUMMER EXAMINATIONS 1999

Second Science Examination
Experimental Physics - (EP 213)

Experimental Physics

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Time allowed : TWO hours.
Answer three questions.

Q.1 What is meant by optical interference ?

Show that the far-field intensity distribution of light in a Young's slits (double slit) interference experiment is given by

$$I = 4I_0 \cos^2\left(\frac{\pi d \sin\vartheta}{\lambda}\right)$$

where the various symbols have their usual meaning. **Note:** The following formulae may be of assistance.

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$$

$$\cos^2 A = \frac{1}{2}(1+\cos 2A)$$

Give a very brief qualitative description of the effect slits of non-negligible width have on the interference pattern obtained.

In a Young's slits experiment, two slits, separated by a distance 1.00 mm, are illuminated with laser light of wavelength 632.8 nm. Interference fringes are viewed on a screen 5.5 m from the slits. Calculate the separation of bright fringes on the screen.

Q.2 State clearly the two postulates of Einstein's Special Theory of Relativity.

Derive, and explain the significance of, the formula

$$L = L_0\sqrt{1-u^2/c^2}$$

Note: You may assume that $\Delta t = \dfrac{\Delta t_0}{\sqrt{1-u^2/c^2}}$

Pions are created in high-energy particle accelerator experiments and are known to have a lifetime of 26 ns at rest. If their speed is 0.90c relative to the accelerator laboratory reference frame, how far will pions travel (as measured in the laboratory reference frame) before decaying ?

p.t.o.

Q.3 Describe the Compton Effect.

Show that when a photon is Compton scattered through an angle ϕ by a free electron, the wavelength of the incident photon λ and the wavelength of the scattered photon λ' are related by the formula

$$\lambda - \lambda' = \frac{h}{m_e c}\left(1-\cos\phi\right)$$

Calculate the maximum energy transferable to a free electron when a 1.17 MeV gamma ray is Compton scattered off a free electron.

Q.4 Answer **both** (a) and (b)

(a) Explain clearly what is meant by nuclear binding energy and indicate where it comes from.

Draw a sketch of the curve relating the binding energy per nucleon to atomic mass number. With reference to the curve drawn, discuss two processes in which nuclear binding energy can be released. Give an example of each process.

(b) Calculate the energy (in joules) released in the following alpha particle decay.

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

What is the speed of the emitted $^{4}_{2}\mathrm{He}$? Justify any assumptions you make in carrying out this calculation.

Q.5 Write detailed notes on **two** of the following.

(i) Heisenberg's uncertainty relationships.

(ii) X-ray spectra.

(iii) Thin film interference.

Electronic charge, e	=	1.60×10^{-19} C
Mass of electron, m_e	=	9.11×10^{-31} kg (≡ 511 keV/c^2)
Mass of proton, m_p	=	1.67×10^{-27} kg
1 u (atomic mass unit)	=	1.66×10^{-27} kg (≡ 931.49 MeV/c^2)
Mass of $^{238}_{92}\mathrm{U}$	=	238.050785 u
Mass of $^{234}_{90}\mathrm{Th}$	=	234.043593 u
Mass of $^{4}_{2}\mathrm{He}$	=	4.002603 u
Planck's constant, h	=	6.63×10^{-34} J s
Velocity of light, c	=	3.00×10^{8} m s^{-1}
Permittivity of free space, ε_0	=	8.85×10^{-12} F m^{-1}
$e^4 m_e / (8\,\varepsilon_0^2 h^2)$	=	13.6 eV (=2.17×10^{-18} J)