UNIVERSITY OF SWAZILAND

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FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2010/11

TITLE O F PAPER:	MODERN PHYSICS & WAVE OPTICS
COURSE NUMBER:	P231
TIME ALLOWED:	THREE HOURS
INSTRUCTIONS:	ANSWER ANY FOUR OUT OF FIVE QUESTIONS
	EACH QUESTION CARRIES 25 MARKS
	MARKS FOR EACH SECTION ARE IN THE RIGHT HAND MARGIN

THIS PAPER HAS SEVEN PAGES INCLUDING THE COVER PAGE

THE LAST PAGE CONTAINS FORMULAE AND CONSTANTS THAT MAY BE USEFUL IN SOME PROBLEMS

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QUESTION 1. 51

(a) Most of the interference experiments discussed in this course deal with the interference of two coherent beams of light. Consider two coherent light waves of the same angular frequency ω moving along the positive x axis towards a screen, and described by the following equations:

$$y_1 = A\sin(kx - \omega t), \text{and}$$

$$y_2 = A\sin(kx - \omega t + \phi).$$

Find the sum of the two waves $y = y_1 + y_2$, describe the wave formed and determine the phase angles ϕ for constructive and destructive interference. **(12 marks)**

Identity: sin(*a*) + sin(*b*) = 2 cos [(*a* - *b*)/2] sin[(*a* + *b*)/2]

(b) In Young's double slit experiment L = 1.420 m, d = 0.0800 mm and the illuminated light has a wavelength λ = 400 nm.

(i) Calculate the phase difference between the two waves fronts arriving at P when θ = 0.500°. **(4 marks)**

(ii) Calculate the phase difference between the two waves fronts arriving at P vertically located by y = 6.00 mm. **(3 marks)**

(iii) What is the value of θ for ϕ = 0.450 rad? **(3 marks)**

(iv) What is the value of θ for the path difference $\delta = \lambda/8$? **(3 marks)**

QUESTION 2

(a) Light from a sodium lamp at the wavelength $\lambda = 589.2$ nm is incident on a single slit of width $d = 0.100$ mm. The viewing screen is placed a distance $L = 2.5$ m from the slit.

(i) Make a labeled diagram that illustrates the intensity distribution of the diffraction pattern of a single slit of width d on a screen a distance L from the slit. **(4 marks)**

(ii) Find the position y_1 of the first dark fringe along the screen. **(4 marks)**

(b) Fully discuss polarization by reflection. **(12 marks)**

(c) What minimum thickness of sodium nitrate will make a quarter-wave plate for the sodium line at a wavelength $\lambda = 589.2$ nm. The indices of refraction for the O and the E rays are $n_O = 1.587$ and $n_E = 1.336$, respectively. **(5 marks)**

QUESTION 3 53

(a) The photoelectric effect is used to find the work function of a particular metal. When green light from a mercury lamp (λ = 546.1 nm) is used, a stopping potential of 0.376 V reduces the photocurrent to zero. What is the work function for this metal?(In solving this problem show how you arrive at the equation used.) **(5 marks)**

(b) Give a detailed discussion of the photoelctric effect, including relevant equations and diagrams, and also give some justification whether this experiment supports the wave or particle nature of light. **(13 marks)**

(c) X-rays having an energy of 320 keV undergo Compton scattering from a target. If the scattering rays are detected at 45° relative to the incident rays, find

(i) the Compton shift at this angle, and **(3 marks)**

(ii) the energy of the scattered X-ray. **(4 marks)**

QUESTION 4

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(a) A hydrogen atom is at its ninth excited state (n = 8). Using the Bohr theory of the atom, calculate

(i) the radius of the orbit, **(2 marks)**

(ii) the linear momentum of the electron, and **(2 marks)**

(iii) the total mechanical energy of the system in electron volts. **(3 marks)**

(b) Calculate the de Broglie wavelength of an electron accelerated with a velocity of 5.6×10^7 m/s. **(3 marks)**

(c) Calculate the de Broglie wavelength for a rifle bullet of mass 150 g moving at a velocity of 500 m/s. Compare the wavelength obtained from this part to that obtained from (c) in this question. **(3 marks)**

(d) This question is on laser operation.

(i) Draw a labeled sketch that illustrates laser operation. **(6 marks)**

(ii) Give the three conditions that must be satisfied for laser operation. **(3 marks)**

(iii)What are the three primary properties of laser light? **(3 marks**

QUESTION 5

55

(a) List the four particles released from natural radioactivity, and also say something about their charges. **(6 marks)**

(b) A Freshly prepared sample of a certain radioactive isotope has an activity of 48.0 mCi. After 48.00 h, its activity is 16.00 mCi.

(i) Find the decay constant and half life of the isotope. **(4 marks)**

(ii) How many nuclei were present in the fresh sample? **(3 marks)**

(c) A dam holds 4.8 x 10^6 kg of water. Of the hydrogen in the water 0.03% is deuterium. The deuterium is to be used in a soon to be developed controlled fusion with the following reaction:

$${}_1^2H + {}_1^2H \rightarrow {}_1^3He + {}_1^1H.$$

(i) Find the Q-value for this reaction. **(3 marks)**

(ii) How much hydrogen is contained in the dam water? **(2 marks)**

(iii) How much of the hydrogen is deuterium? **(2 marks)**

(iv) How many deuterium atoms are in the hydrogen? **(2 marks)**

(v) If a 40% efficient power plant is to be constructed to use the deuterium as a fuel, what is the power capacity of the plant if it is to be operated for a year? **(3 marks)**

SOME INFORMATION THAT MAY BE USEFUL IN SOME PROBLEMS 56

Avogadro's number A = 6.02 x 10^{23} particles per mole
Stefan-Boltzmann Constant σ = 5.669 6 x 10^{-8} W/(m^2K^2)^3
Coulomb constant k_e = 8.987 551 788 x 10^9 N.m^2/C^2
Boltzmann's constant, k_B = 1.3801 x 10^{-23} J/K
Bohr radius a_0 = 5.291 772 x 10^{-11} m
Bohr magneton, μ_B = 9.27 x 10^{-24} J/T
Radii of orbit for the hydrogen aton $r_n = n^2\, a_0$
Planck's constant, h = 6.626 075 x 10^{-34} Js
$\hbar$ = 1.054 572 x 10^{-34} Js
hc = 1.986 447 x 10^{-25} Jm
$2\pi hc^2$ = 3.741 859 x 10^{-15} Jm^2s-1
Rydberg constant R_H = 1.097 373 x 10^7 m^{-1}.
Speed of light in vacuum, c = 2.997 924 58 x 10^8 m/s
mass of an electron, m_e = 9.109 389 7 x 10^{-31} kg = 0.000 548 6 u
mass of a proton, m_p = 1.672 623 x 10^{-27} kg = 1.007 276 u
mass of a neutron, m_n = 1.674 928 6 x 10^{-27} kg = 1.008 665 u
Coulomb constat, k_e = 8.987 551 787 x 10^9 Nm^2/C^2
electron charge, e = 1.602 177 33 x 10^{-19} C
1 atomic mass unit = 1 amu = 1 u = 1.660 540 2 x 10^{-27} kg ≡ 931.494 MeV rest mass energy
1 eV = 1.602 177 33 x 10^{-19} J
$T_{1/2}(^{14}C)$ = 5730 years

Ratio of carbon 14 to carbon 12 in the atmosphere, $\frac{N(^{14}C)}{N(^{12}C)} = 1.2987x10^{-12}$

r_0 = 1.2 x 10^{-15} m.

Helium (^4He) mass = 4.002 603 u
Molybdenum (^{94}Mo) mass = 93.905 088 u
Ruthenium (^{98}Ru) mass = 97.905 287 u
Cerium (^{140}Ce) mass = 139.905 434 u
Neodymium (^{144}Nd) mass = 143.910 083 u
Iron (^{56}Fe) mass = 55,934 942 u.

$$\lambda_{max} = \frac{hc}{4.965kT}$$

$$\theta_{min} = 1.22\lambda/D$$