UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

RE-SIT EXAMINATION 2017/2018

TITLE OF PAPER: MODERN PHYSICS AND WAVE OPTICS

COURSE NUMBER: PHY232

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 6 PAGES INCLUDING THE COVER PAGE.

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QUESTION 1

(a) In a double-slit arrangement of Figure 1, $d = 0.150$ mm, $L = 140$cm and $\lambda = 643$nm.

(i) What is the path difference δ for the rays from the two slits arriving at P, if ($y = 1.80$cm)?

(4 marks)

(ii) For $y = 1.80$cm, express this path difference in terms of λ.

(3 marks)

(iii) Does P correspond to a maximum, a minimum, or an intermediate condition, given that $y = 1.80$cm?

(2 marks)

(iv) Calculate the distance y above the central maximum for which the average intensity on the screen is 75.0% of the maximum.

(6 marks)

(b) An oil film ($n = 1.45$) floating on water is illuminated by white light at normal incidence. The film is 280 nm thick. A typical human eye will respond to wavelengths from 390nm to 700nm. Find:

(i) The wavelength (or color) of the light in the visible spectrum most strongly reflected. Explain your reasoning.

(5 marks)

(ii) The wavelength (or color) of the light in the spectrum most strongly transmitted. Explain your reasoning.

(5 marks)

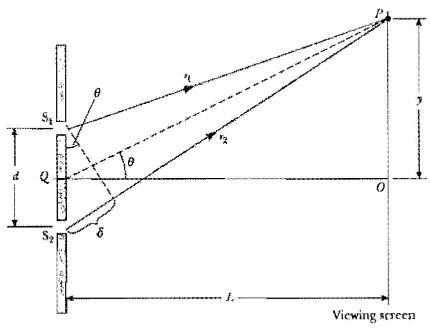

Figure 1:

QUESTION 2

(a) Light of wavelength 587.5 nm illuminates a single slit 0.750 mm in width.

(i) At what distance from the slit should a screen be located if the first minimum in the diffraction pattern is to be 0.850 mm from the center of the principal maximum?

(4 marks)

(ii) What is the width of the central maximum?

(2 marks)

(b) The pupil of a cat's eye narrows to a vertical slit of width 0.500 mm in daylight. What is the angular resolution for horizontally separated mice? Assume that the average wavelength of the light is 500 nm.

(3 marks)

(c) Three discrete spectral lines occur at angles of 10.09°, 13.71°, and 14.77° in the first-order spectrum of a grating spectrometer.

(i) If the grating has 3 660 slits/cm, what are the wavelengths of the light?

(6 marks)

(ii) At what angles are these lines found in the second-order spectrum?

(6 marks)

(d) The angle of incidence of a light beam onto a reflecting surface is continuously variable. The reflected ray is found to be completely polarized when the angle of incidence is 48.0°. What is the index of refraction of the reflecting material?

(4 marks)

QUESTION 3

(a) The wavelength of maximum intensity of the sun's radiation is observed to be near 500 nm. Assume the sun to be a blackbody and calculate :

(i) The sun's surface temperature.

(3 marks)

(ii) The power per unit area $P(T)/A$ emitted from the sun's surface.

(3 marks)

(iii) The energy received by the Earth each day from the sun's radiation. The radius of the sun is 6.96×10^5 km, the radius of the earth is 6.37×10^6 m and the mean earth-sun distance is 1.49×10^{11} m.

(5 marks)

(b) (i) What frequency of light is needed to produce electrons of kinetic energy 3.00 eV from illumination of lithium?

(3 marks)

(ii) Find the wavelength of this light.

(3 marks)

(c) (i) Calculate the de Broglie wavelength for an electron (me 5 9.11 3 10231 kg) moving at 1.00 3 107 m/s. Can the wave nature of this electron be detected by diffraction?

(4 marks)

(ii) A rock of mass 50 g is thrown with a speed of 40 m/s. What is its de Broglie wavelength? Can the wave nature of this rock could be detected by diffraction?

(4 marks)

QUESTION 4

(a) (i) What is the energy of a hydrogen atom when the electron is in the 3^{rd} orbital?

(3 marks)

(ii) What is the radius of the electron's Bohr orbit.

(2 marks)

(iii) What is the de-Broglie wavelength of the electron in this orbit.

(4 marks)

(iv) If the electron decays to the 2^{nd} orbital, what is the frequency of the photon that is emitted?

(4 marks)

(v) What is the wavelength of the photon that is emitted?

(3 marks)

(vi) Calculate the wavelength using the empirical Balmer-Rydberg equation and compare to the results from the Bohr model.

(4 marks)

(b)

(i) In interstellar space, highly excited hydrogen atoms called Rydberg atoms have been observed. Find the wavelength to which radio astronomers must tune to detect signals from electrons dropping from the $n - 273$ level to the $n = 272$ level.

(3 marks)

(ii) What is the radius of the electron orbit for a Rydberg atom for which $n = 273$?

(2 marks)

QUESTION 5

(a) Consider the isotope Europium-131 ($^{131}_{63}Eu$), with mass 121919.966 MeV. Given its A and Z numbers, do you expect this isotope to be stable? ($r_0 = 1.2fm$)

(5 marks)

(b) The mass of Samarium-130 is 120980.755 MeV. What is the Q-value for the reaction

$$^{131}_{63}Eu \rightarrow {}^{130}_{62}Sa + {}^{1}_{1}H$$

(6 marks)

(c) Calculate the frequency $f = v/R$ for the photon to be at the edge of the Coulomb potential. Here R is the Samarium radius and v the proton speed when taking Q as the (classical) kinetic energy.

(7 marks)

(d) What is the Coulomb potential, $V_C(R)$, at the distance R? What is the distance R_C at which the Coulomb potential is equal to the Q-value?

(7 marks)

SOME INFORMATION THAT MAY BE USEFUL IN SOME PROBLEMS

Avogadro's number A = 6.02 x 10^{23} particles per mole
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
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} J·m^2·s^{-1}
Radii of orbit for the hydrogen atom $r_n = n^2 a_0$
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
Stefan-Boltzmann Constant σ = 5.669 6 x 10^{-8} W/(m^{2}K^2)
Wien's displacement law $\lambda_{max} = \frac{hc}{4.965 k_B T}$

Nuclear Data

Electron charge, e = 1.602 177 33 x 10^{-19} C
Electron mass, m_e = 9.109 389 7 x 10^{-31} kg = 0.000 548 6 u
Neutron, m_n = 1.674 928 6 x 10^{-27} kg = 1.008 665 u
Proton mass, m_p = 1.672 623 x 10^{-27} kg = 1.007 276 u

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: 1 MeV = 1.602 177 33 x 10^{-13} J
$T_{1/2}(^{14}C)$ = 5730 years
Ratio of carbon 14 to carbon 12 in the atmosphere = $\frac{N(^{14}C)}{N(^{12}C)} = 1.2987 \times 10^{12}$
1Curie (Ci) = 3.7 x 10^{10} Becquerel (Bq)
r_0 = 1.2 x 10^{-15} m

Cerium (^{140}Ce) atomic mass = 139.905 434 u
Deuterium (^{2}D) atomic mass = 2.014 102 u
Alpha particle (α) (^{4}He) atomic mass = 4.002 603 u
Hydrogen (^{1}H) atomic mass = 1.007 825 u
Hydrogen molecular mass = 1.007 94 u
Iron (^{56}Fe) atomic mass = 55.934 942 u
Molybdenum (^{94}Mo) mass = 93.905 088 u
Neodymium (^{144}Nd) atomic mass = 143.910 083 u
Oxygen ^{15}O atomic mass = 15 .003 065 u
Nitrogen ^{15}N atomic mass = 15.000 109 u
Radium ($^{226}_{88}Ra$) atomic mass = 226.025 403 u
Radon ($^{222}_{86}Rn$) atomic mass = 222.017 570 u
Ruthenium (^{98}Ru) atomic mass = 97.905 287 u
Tritium (^{3}T) atomic mass = 3.016 049 u
$\sin^2\theta = \frac{1}{2}(1 - \cos 2\theta)$