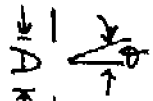
Physics 116A - Final Examination

Summer 1992 - Oscar E. Vilches

This is the formula page. You may tear it off if you wish.

MAKE SURE TO WRITE YOUR NAME ON THE NEXT PAGE

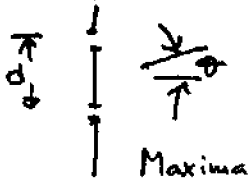
Single slit diffraction



First zero

$D \sin\theta = m\lambda$

Double slit interference



Maxima: $d\sin\theta = n\lambda$

Zeroes: $d\sin\theta = (n+\frac{1}{2})\lambda$

Constants

$e = 1.6\times10^{-19}\,C$ (charge of electron)

$m_e = 9.11\times10^{-31}\,kg$ (mass of electron)

$m_p = 1.6726\times10^{-27}\,kg$ (mass of proton)

$m_n = 1.6749\times10^{-27}\,kg$ (mass of neutron)

$h = 6.63\times10^{-34}\,Js$ (Planck's constant)

$\hbar = \frac{h}{2\pi} = 1.06\times10^{-34}\,Js$ (h-bar)

$c = 3\times10^{8}\,\frac{m}{s}$ (speed of light in vacuum)

Photons

Energy $= hf = \frac{hc}{\lambda}$ (in vacuum)

Particles

Energy (non relativistic)

Kinetic $= \frac{1}{2}mv^2 = \frac{p^2}{2m}$

Momentum $= p = mv$ (particle)

$p = \frac{h}{\lambda}$ (wave)

For charged particles in a potential difference V, the Potential Energy $= qV$ where q is the charge of the particle.

Units

1 electron Volt (eV) $= 1.6\times10^{-19}$ Joules

Geometry

- Perimeter of circle: $2\pi r = \pi D$
- Area of circle: $\pi r^2 = \pi\left(\frac{D}{2}\right)^2$
- Area of sphere: $4\pi r^2$
- Volume of sphere: $\frac{4}{3}\pi r$

Hydrogen atom

$E_n = -13.6\,eV\,\frac{1}{n^2}$

Quantum numbers

n = principal

ℓ = orbital ($< n$)

m_ℓ = magnetic ($-\ell \le m_\ell \le \ell$)

s = spin $\{+\frac{1}{2}$ or $-\frac{1}{2}$

$A \rightarrow 16$

$Z \rightarrow 8$ (Element)

$A - Z$ = number of neutrons.

PERIODIC TABLE OF THE CHEMICAL ELEMENTS

H^{1} 1s																	He^{2} 1s^2
Li^{1} 2s	Be^{1} 2s^2											B^{1} 2s^{2}2p	C^{1} 2s^{2}2p^2	N^{1} 2s^{2}2p^3	O^{1} 2s^{2}2p^4	F^{1} 2s^{2}2p^5	Ne^{18} 2s^{2}2p^6
Na^{11} 3s	Mg^{11} 3s^2											Al^{11} 3s^{2}3p	Si^{11} 3s^{2}3p^2	P^{15} 3s^{2}3p^3	S^{15} 3s^{2}3p^4	Cl^{11} 3s^{2}3p^5	Ar^{18} 3s^{2}3p^6
K^{19} 4s	Ca^{20} 4s^2	Sc^{11} 3d 4s^2	Ti^{20} 3d^2 4s^2	V^{11} 3d^3 4s^2	Cr^{24} 3d^5 4s	Mn^{25} 3d^5 4s^2	Fe^{26} 3d^6 4s^2	Co^{11} 3d^7 4s^2	Ni^{28} 3d^8 4s^2	Cu^{11} 3d^{10} 4s	Zn^{30} 3d^{10} 4s^2	Ga^{11} 4s^{2}4p	Ge^{11} 4s^{2}4p^2	As^{11} 4s^{2}4p^3	Se^{11} 4s^{2}4p^4	Br^{11} 4s^{2}4p^5	Kr^{36} 4s^{2}4p^6
Rb^{11} 5s	Sr^{38} 5s^2	Y^{11} 4d 5s^2	Zr^{40} 4d^2 5s^2	Nb^{11} 4d^4 5s	Mo^{11} 4d^5 5s	Tc^{11} 4d^6 5s	Ru^{11} 4d^7 5s	Rh^{11} 4d^8 5s	Pd^{46} 4d^{10} -	Ag^{11} 4d^{10} 5s	Cd^{48} 4d^{10} 5s^2	In^{11} 5s^{2}5p	Sn^{50} 5s^{2}5p^2	Sb^{11} 5s^{2}5p^3	Te^{11} 5s^{2}5p^4	I^{11} 5s^{2}5p^5	Xe^{11} 5s^{2}5p^6
Cs^{11} 6s	Ba^{56} 6s^2	La^{11} 5d 6s^2	Hf^{11} 4f^{14} 5d^2 6s^2	Ta^{11} 5d^3 6s^2	W^{11} 5d^4 6s^2	Re^{11} 5d^5 6s^2	Os^{11} 5d^6 6s^2	Ir^{11} 5d^7 6s^2	Pt^{78} 5d^9 6s	Au^{11} 5d^{10} 6s	Hg^{80} 5d^{10} 6s^2	Tl^{11} 6s^{2}6p	Pb^{82} 6s^{2}6p^2	Bi^{11} 6s^{2}6p^3	Po^{11} 6s^{2}6p^4	At^{11} 6s^{2}6p^5	Rn^{86} 6s^{2}6p^6
Fr^{11} 7s	Ra^{88} 7s^2	Ac^{11} 6d 7s^2															

Ce^{58} 4f^2 6s^2	Pr^{59} 4f^3 6s^2	Nd^{60} 4f^4 6s^2	Pm^{11} 4f^5 6s^2	Sm^{11} 4f^6 6s^2	Eu^{11} 4f^7 6s^2	Gd^{11} 4f^7 5d 6s^2	Tb^{11} 4f^9 6s^2	Dy^{11} 4f^{10} 6s^2	Ho^{11} 4f^{11} 6s^2	Er^{11} 4f^{12} 6s^2	Tm^{11} 4f^{13} 6s^2	Yb^{11} 4f^{14} 6s^2	Lu^{11} 4f^{14} 5d 6s^2
Th^{90} - 6d^2 7s^2	Pa^{11} 5f^2 6d 7s^2	U^{11} 5f^3 6d 7s^2	Np^{11} 5f^4 7s^2	Pu^{11} 5f^6 7s^2	Am^{11} 5f^7 7s^2	Cm^{11} 5f^7 6d 7s^2	Bk^{11}	Cf^{11}	Es^{11}	Fm^{11}	Md^{11}	No^{11}	Lr^{11}

Decay rates

$$\Delta N = -\lambda N \Delta t$$

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

$$N = N_0 e^{-\lambda t}$$

$$\lambda = \frac{0.693}{t_{1/2}} \quad \text{or} \quad t_{1/2} = \frac{0.693}{\lambda}$$

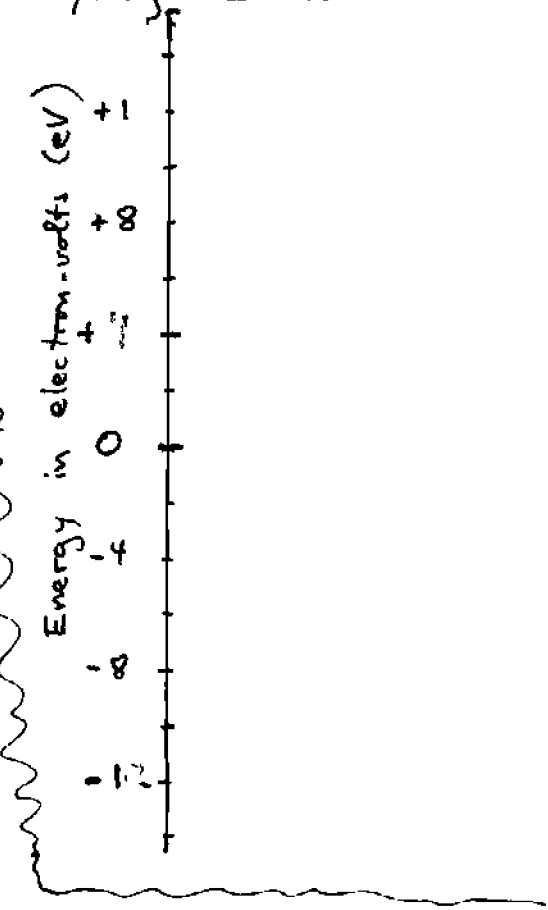
NAME: _____

FINAL EXAM
PHYSICS 116A, Summer 1992, O.E. Vilches

PROBLEM 1 (27 points)

This problem has questions related to the hydrogen atom.

(7) a) In the energy axis (or scale) at right, make a quantitative "guess" as to the location of the lowest four energy states of hydrogen and draw a horizontal line to show them



(5) b) A hydrogen atom makes a transition from a 4p state to a 1s state. Write the principal and orbital quantum numbers of the initial and final states, and indicate the transition in your energy levels of part (a)

(8) c) Calculate the wavelength of the emitted radiation in the transition of part (b). Is your calculated wavelength in the ultraviolet, visible, or infrared portion of the electromagnetic spectrum?

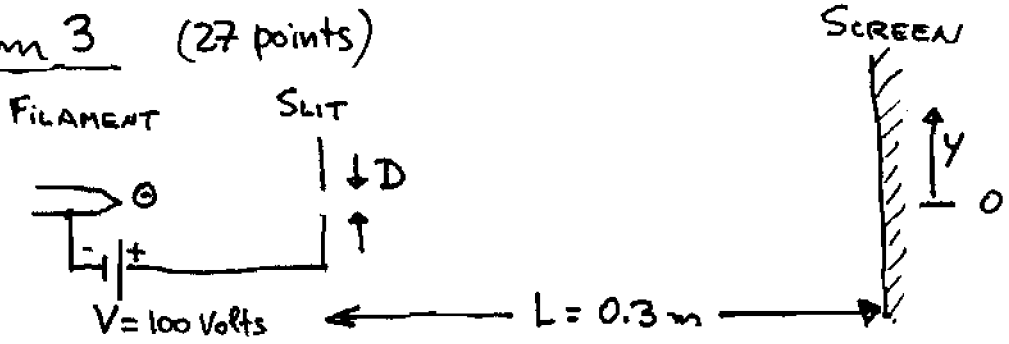
(7) d) In the Bohr formula for the energy levels of hydrogen derived in this course, does it make any difference if the atom you are describing is hydrogen (^1_1H) or its isotope deuterium (^2_1H)? Write a short sentence for answer.

PROBLEM 2 (20 points)

(10) (a) Write the quantum numbers for each one of the electrons in Neon ($^{20}_{10}Ne$)

(10) (b) Estimate (calculate, but the calculation is not exact) the energy of a 1s (one) electron in $^{20}_{10}Ne$

Problem 3 (27 points)



Electrons are produced by a FILAMENT (with zero initial velocity). They are accelerated by a 100 Volts potential difference and go through a SLIT of diameter D. A screen (like in a TV tube) records the arrival of the electrons. The distance between the SLIT and the SCREEN is $L = 0.3\,m$.

(9) (a) Show that the wavelength of the electrons going through D is $1.23 \times 10^{-10}\,m$.

(10) (b) Calculate the size of the slit D so that the first diffraction zero occurs at $Y = 0.05\,m$

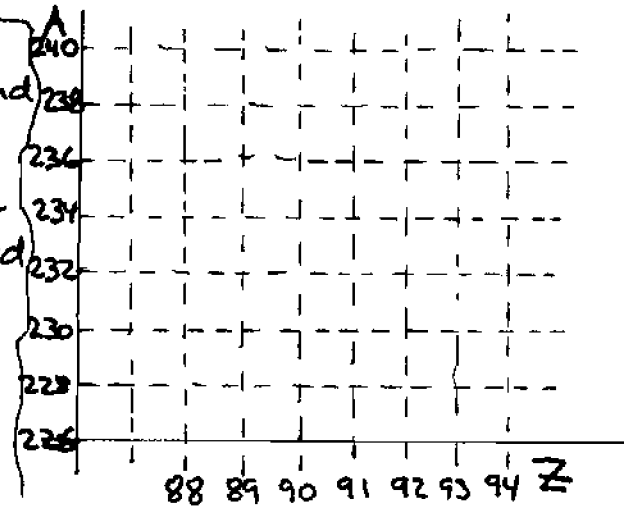
(8) (c) Heisenberg's uncertainty principle states that for electrons going through D the uncertainty in the y-position ($\Delta y = D$) and the uncertainty in the y-momentum of the electrons are related by $\Delta y\, \Delta p_y \geq \hbar$. Show that the condition for an electron hitting the screen within the first diffraction zero above or below $\theta = 0$ is in agreement with Heisenberg's principle (work on back, generous credit for a reasonable answer)

PROBLEM 4 (26 Points)

6/6

The $^{238}_{92}U$ decay series has this isotope decaying to $^{A'}_{Z'}Th$ by α-particle emission. This Th isotope goes to $^{A''}_{Z''}Pa$ by β emission, followed by a transformation to $^{A'''}_{Z'''}U$ by β-particle emission, and to $^{A''''}_{Z''''}Th$ by α-particle emission.

(10) (a) Find $A', A'', A''', A'''', Z', Z'', Z''', Z''''$, and write below each one of the nuclear reactions in this chain until you reach $^{A''''}_{Z''''}Th$. Map the path followed in the A vs Z grid at right.



(8) (b) If the half life of $^{230}_{90}Th$ was 8×10^4 years and you had half a mole of it (about 3×10^{23} atoms) how many particles do you expect to decay per second? (Calculate the number)

(8) (c) If the α-particles emitted in part (b) are emitted in all directions of space, calculate how many counts/second a circular detector of 1 cm diameter will record if it is located 20 cm away from the source.

SCORE	
PROB. 1	(27)
PROB. 2	(20)
PROB. 3	(27)
PROB. 4	(26)
Total	(100)