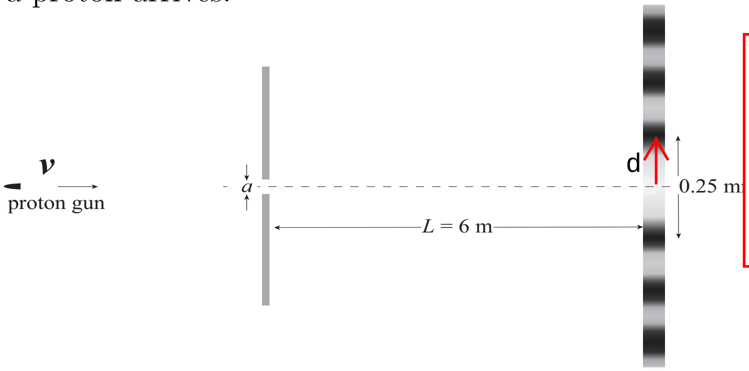
Physics 102 (F16) Q13A

Name: ____________________ **Section:** __________ **Score:** __________/20

1. Protons are sent one by one with the same speed v through a narrow slit of width $a = 9\ \mu\text{m}$ $(= 9 \times 10^{-6}\ \text{m})$. 6 m away from the slit is a detector bank on which we observe a bright spot when a proton arrives.

de Broglie wave
lambda = h/p
p = mv



diffraction
dark fringe positions
n lambda = a sin theta

small angle approximation
n lambda = a(d/L)

(1) Collecting all the results of numerous protons, we can observe a diffraction pattern whose central peak has width 0.25 mm. What is the speed v of the protons? [5]

We can determine the wavelength of the proton as
lambda = a{d/L), where a = 9 x 10^{-6}, d = (0.25/2)x10^{-3}, L = 6; n = 1.
Therefore,
lambda = 9x10^{-6} x (0.25/12)x10^{-3} = 0.1875x10^{-9} m.

This means p = h/lambda = 6,626x10^{-34}/0.1875x10^{-9} = 35.2x10^{-25},
so v = p/m = 35.2x10^{-25}/1.6x10{-27} = 21x10^2 = 2.1 km/s

(2) If the kinetic energy of the protons is doubled, what is the width of the central diffraction peak now? [5]

waves with smaller lambda go more straight. See the figure on p 141.
Large p gives smaller lambda; more ballistic.

K = p^2/2m

K -> 2K implies p -> sqrt{2}P, which implies lambda -> lambda/sqrt{2},
so the pattern shrinks: 0.25/sqrt{2} = 0.178 mm

2. When the surface of a metal is illuminated with photons of wavelength 293 nm. The speed of the fastest photoelectron ejected from the surface has a speed of 391 km/s.

(1) What is the work function W in eV of the metal? [5]

1240/lambda = enegy in eV

max K = h f - W

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hf = 1240/293 = 4.23 eV (incident light)
v = 391 km/s -> Kmax = (1/2)mv^2 = (1/2) x 9.11x10^{-21} (391x10^3)^2 (in J)
                     = (9.11x391^2/2x1.6) x 10^{-31+6+19} = 0.453 eV
Therefore, W = 4.23 - 0.453 = 3.8 eV.
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(2) The photon is actually produced by a deexcitation of an excited Li^{2+} ion to the state with principal quantum number $n = 4$. What is the principal quantum number of the initial excited state of the ion? [5]

En = -13.6Z^2/n^2

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so hf = 13.6Z^2(1/nfinal^2 -1/ninitial^2).

Z = 3 for our case.
4.23 = 13.6x9(1/16 - 1/x^2).

Therefore,
1/x^2 = 1/16 - 0.0345 = 1/35.7 -> n = 6 initial.
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