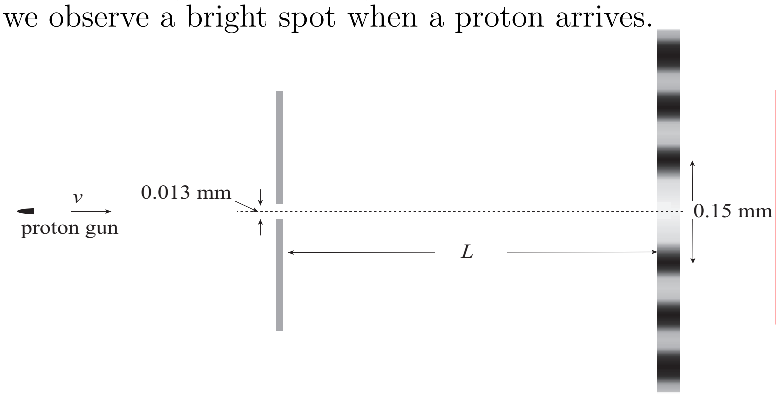
Physics 102 (F16)

Q13B

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

1. Protons are sent one by one with the same speed $v = 2.5$ km/s from far behind a narrow slit of width 13 μm (see the figure). Distance L away from the slit is a detecting screen 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 with the spacing between the two first dark fringes being 0.15 mm. What is the distance L? [5]

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p = mv = 1.673x10^{-27} x 2.5x10^3, so
de Broglie wavelength = 6,626x10^{-34}/2.5x1.673 x10^{-24} = 1.58x10^{-10} m.
We can determine L from lambda = a{d/L) as
            L = a(d/lambda)
where a = 13 x 10^{-6}, d = (0.13/2)x10^{-3},  n = 1, so
      L = 13x10^{-6} x 0.13x10^{-3}/2x1.58x10^{-10} = 6.17 m.
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(2) If the kinetic energy of the protons is halved, what is the spacing between the two first dark fringes? [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

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K -> K/2  implies p -> p/sqrt{2}, which implies lambda -> sqrt{2}lambda,
so the pattern expands: 0.15xsqrt{2} = 0.212 mm
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2. When the surface of a metal is illuminated with photons of wavelength 486 nm, we find that the speed of the fastest photoelectron ejected from the surface has a speed of 337 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 = 1240/486 = 2.55 eV (incident light)
v = 337 km/s -> Kmax = (1/2)mv^2 = (1/2) x 9.11x10^{-21} (337x10^3)^2 (in J)
                     = (9.11x337^2/2x1.6) x 10^{-31+6+19} = 0.323 eV
Therefore, W = 2.55 - 0.323 = 2.23 eV.
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(2) The photon is actually produced by a deexcitation of a hydrogen atom to the state with principal quantum number $n = 2$. What is the principal quantum number of the initial excited state? [5]

En = -13.6Z^2/n^2

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

Z = 1 for our case.
2.55 = 13.6 (1/4 - 1/x^2).

Therefore,
1/x^2 = 1/4 - 0.1875 = 1/16 -> n = 4 initial.
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