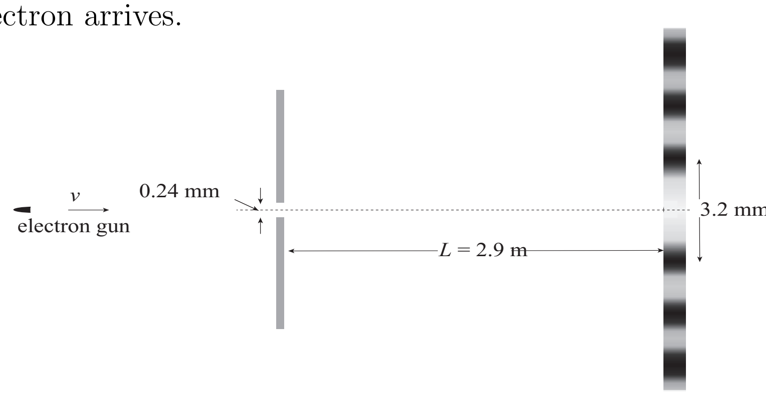
Physics 102 (F16)

Q13C

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

1. Electrons are sent one by one with the same speed v from far behind a single slit of width 0.24 mm. 2.9 m away from the slit is a detecting screen on which we observe a bright spot when an electron 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 electrons, we can observe diffraction patterns with the spacing between the two first dark fringes being 3.2 mm. What is the speed v of the electrons? [5]

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We can determine the wavelength of the proton as
lambda = a{d/L), where a = 24 x 10^{-6}, d = (3.2/2)x10^{-3}, L = 2.9; n = 1.
Therefore,
   lambda = 24x10^{-5} x (1.6/2.9)x10^{-3} = 13.2x10^{-8} m.

This means p = h/lambda = 6.626x10^{-34}/1.3x10^{-7} =  5.02x10^{-27}
             = 9.11x10^{-31} v,
so v = p/m = 5.02x10^{-27}/9.11x10{-31} = 0.559x10^4 m/s = 5.59 km/s
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(2) If the kinetic energy of the electrons is doubled (compared with the case (1)), what is the spacing between the two first dark fringes 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

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K -> 2K  implies p -> sqrt{2}P, which implies lambda -> lambda/sqrt{2},
so the pattern shrinks: 3.2/sqrt{2} = 2.26 mm
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2. When the surface of a metal is illuminated with photons of wavelength 164 nm. The speed of the fastest photoelectron ejected from the surface has a speed of 790 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 = 1240/164 = 7.56 eV (incident light)
v = 790 km/s -> Kmax = (1/2)mv^2 = (1/2) x 9.11x10^{-21} (790x10^3)^2 (in J)
                     = (9.11x790^2/2x1.6) x 10^{-31+6+19} = 1.78 eV
Therefore, W = 7.56 - 1.78 = 5.78 eV.
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(2) The photon is actually produced by a deexcitation of an excited He^+ ion 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 = 2 for our case.
7.56 = 13.6x4(1/4 - 1/x^2).

Therefore,
1/x^2 = 1/4 - 0.138 = 1/8.93 -> n = 3 initial.
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