PROBLEM 1

WITH PLANK'S CONSTANT, h, AND MOMENTUM, p, GIVEN BY $p = m \cdot v = (1.2\,kg)(6.0\,m/s) = 7.2\,kg\,m\,s^{-1}$

WE HAVE A DE BROGLIE WAVELENGTH OF

$$\lambda = \frac{h}{p} = \frac{6.626 \cdot 10^{-34}\ J \cdot s}{7.2\,kg\,m\,s^{-1}}$$

$$= 0.92 \cdot 10^{-34}\ \cancel{kg} \cdot m^{\cancel{2}} \cdot \cancel{s^{-2}} \cdot \cancel{s}\ \cancel{kg^{-1}}\,\cancel{m^{-1}}\,\cancel{s}$$

$$= \boxed{0.92 \cdot 10^{-34}\ m}.$$

THIS IS A VANISHINGLY SMALL WAVELENGTH. THIS MIGHT PRODUCE RIPPLES IN THE SURFACE OF THE WATER OF $\sim 0.5\,m$ WAVELENGTH.

PROBLEM 2

a.) $K = \frac{3}{2}\left(1.381 \cdot 10^{-23} \, JK^{-1}\right)(293K) = \boxed{6.01 \cdot 10^{-21} J}$

b.) NOW WITH $K = 6.01 \cdot 10^{-21} = \frac{m \cdot v^2}{2}$

WE HAVE $2\sqrt{m} \cdot v = \sqrt{6.01 \cdot 10^{-21}}$ AND

$\lambda = \frac{h}{m \cdot v} = \frac{h}{2 \cdot m \frac{\sqrt{6.01 \cdot 10^{-21}}}{\sqrt{m}}}$. GOOGLE GIVES

THE MASS OF A NEUTRON AS $1.67 \cdot 10^{-27} kg = m$

$\Rightarrow \lambda = 1 \cdot 10^{-10} \, m = \boxed{0.1 \, nm}$.

Problem 3

With $T = 310.15\,K$, $K = \frac{3}{2} \cdot (1.381 \cdot 10^{-23}\,J K^{-1})(310.15\,K)$

$= 6.4 \cdot 10^{-21}\,J$.

Now $\lambda = \dfrac{h}{\sqrt{2Km}}$

$= \dfrac{6.626 \cdot 10^{-34}\,J.s}{\sqrt{2\,(6.4 \cdot 10^{-21}\,J)(28.02\,g/mol \cdot N_A)}}$

$p = m \cdot v$ + $K = \frac{1}{2} m v^2$

$\Rightarrow K = \frac{1}{2} m \left(\frac{p}{m}\right)^2$

$\Rightarrow p^2 = 2Km$

$\Rightarrow p = \sqrt{2Km}$

With $28.02\,g$ the mass of two nitrogens and N_A the number of atoms per mol.

This gives:

$$\lambda = \frac{6.626 \cdot 10^{-34}\,kg \cdot m^2 \cdot \cancel{s} / \cancel{s}}{\sqrt{2\,(6.4 \cdot 10^{-21}\,kg \cdot m^2 / s^2)(.02802\,kg / 6.022 \cdot 10^{23})}}$$

$= \boxed{8.6 \cdot 10^{-12}\,m.}$

PROBLEM 4 (# 17 KRANE)

IF $\Delta V = 2 \cdot 10^4 \, m/s$, $\Delta p = m_e \Delta V$ AND

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2} \Rightarrow \Delta x \geq \frac{\hbar}{\Delta p}$$

$$\Rightarrow \Delta x \geq \frac{1.05 \cdot 10^{-34} \, J \cdot s}{m_e \Delta V}$$

$$\Rightarrow \Delta x \geq \frac{1.05 \cdot 10^{-34} \, \cancel{kg} \, m^2 \cancel{s^{-2}} \cdot s}{(9.12 \cdot 10^{-31} \, \cancel{kg})(2 \cdot 10^4 \, m \, s^{-1})}$$

$$= 5.76 \cdot 10^{-9} \, m = \boxed{5.76 nm}$$

WHERE m_e IS THE MASS OF AN ELECTRON.

5.76nm IS THE LOWEST THE UNCERTAINTY IN POSITION CAN POSSIBLY BE, SO THIS IS THE SMALLEST REGION WHEREIN THE ELECTRON CAN BE CONFINED.

PROBLEM 5

FOR AN IDEAL GAS, $PV = nRT \Rightarrow n = \frac{PV}{RT}$

$$\Rightarrow n = \frac{1\,atm \cdot 1\,m^3}{8.3145\,kg\,m^2 s^{-2} K^{-1} mol^{-1} \cdot 300K} = \frac{101325\,\cancel{kg}\,\cancel{m^{-1}}\,\cancel{s^{-2}} \cdot \cancel{m^3}}{8.3145\,\cancel{kg}\,\cancel{m^2}\,\cancel{s^{-2}}\,\cancel{K^{-1}}\,mol^{-1}\,300\cancel{K}}$$

$$= 40.62\ mol$$

n IS THE NUMBER OF MOLES PER m^3 ASSUMING AN IDEAL GAS AT 300 K AND 1 ATMOSPHERE. THIS IMPLIES $40.62 \cdot 6.022 \cdot 10^{23}$ MOLECULES PER m^3. IF WE ASSUME THIS GIVES EACH MOLECULE A $\frac{1\,m^3}{40.62 \cdot 6.022 \cdot 10^{23}}$ CUBE TO CALL THEIR OWN, AND THEY LIVE IN THE MIDDLE OF THAT CUBE, THEY SHOULD BE ROUGHLY $\sqrt[3]{\frac{1\,m^3}{40.62 \cdot 6.022 \cdot 10^{23}}} = 3.44 \cdot 10^{-9}\,m = 3.44\,nm$ APART.

WE FOUND A WAVELENGTH 3 ORDERS OF MAGNITUDE SHORTER IN PROBLEM 3. WE SHOULD NOT, THEREFORE, OBSERVE QUANTUM BEHAVIOR FROM THEM.

PROBLEM 6 (#5 KRANE)

USING THE λ's PROVIDED WE CAN FIND THE VOLTAGE DIFFERENCE NEEDED BY FINDING THE KINETIC ENERGY NEEDED (AND THEN DROP THE "e" FROM eV). FIRST,

$$KE = \frac{1}{2} m_e v^2 = \frac{1}{2} m_e \left(\frac{p}{m_e}\right)^2 = \frac{p^2}{2 m_e} \quad \& \quad p = \frac{h}{\lambda}$$

$$\Rightarrow \quad KE = \frac{1}{2m_e}\left(\frac{h}{\lambda}\right)^2 .$$ THEREFORE,

(a)

WHERE $\lambda = 12 \cdot 10^{-9}$ m WE HAVE THAT

$$KE = \frac{1}{2(.511 \cdot 10^6 \, eV/\cancel{c^2})} \cdot \left(\frac{4.136 \cdot 10^{-15} \, eV\cancel{s}}{12 \cdot 10^{-9} \, m}\right)^2 = \boxed{.01 \, eV}$$

OR A POTENTIAL DIFFERENCE OF $\boxed{.01 V}$.

(b) WHERE $\lambda = 0.12 \cdot 10^{-9}$ WE HAVE

$KE = \boxed{97 eV}$ OR A POTENTIAL DIFFERENCE OF $\boxed{97 V}$

(c) WHERE $\lambda = 1.2 \cdot 10^{-15}$

$KE = \boxed{9.7 \cdot 10^{11} \, eV}$ OR POTENTIAL DIFFERENCE OF $\boxed{9.7 \cdot 10^{11} V}$.

PROBLEM 7 (#11 KRANE)

IF THE ELECTRONS ARE ACCELERATED THROUGH 175 V, WE CAN ASSUME THE HAVE 175 eV OF KINETIC ENERGY WHICH WE CAN RELATE TO MOMENTUM AS FOLLOWS:

$$p = \sqrt{2 m_e K} = \sqrt{2\left(1.9 \cdot 10^{-31}\,\mathrm{kg}\right)\left(2.8 \cdot 10^{-17}\,\mathrm{kg\,m^2 s^{-2}}\right)}$$

$$= 7.14 \cdot 10^{-24}\,\mathrm{kg \cdot m\,s^{-1}}.$$

WITH THIS WE CAN FIND THE DE BROGLIE WAVELENGTH AS FOLLOWS:

$$\lambda = \frac{h}{p} = 9.28 \cdot 10^{-11}\,\mathrm{m}.$$

WITH AN EXPERIMENTAL SETUP AS IN FIGURE 4.6, WE CAN FIND THE CONSTRUCTIVE ANGLES AS FOLLOWS:

$$\boxed{\phi =} \sin^{-1}\left(\frac{n\lambda}{d}\right) = \boxed{\sin^{-1}\left(\frac{n\left(9.28 \cdot 10^{-11}\,\mathrm{m}\right)}{0.352 \cdot 10^{-9}\,\mathrm{m}}\right) \quad \forall n \in \mathbb{Z}^+}.$$

PROBLEM 8

a.) $s = 2.998 \cdot 10^{8}\ m/s$ + $d = 1.2 \cdot 10^{-15}\ m$

$$\Rightarrow \quad \Delta t = \frac{d}{s} = \boxed{4 \cdot 10^{-24}\ s}$$

b.) EQUATION 4.14 GIVE THE ENERGY UNCERTAINTY

AS $\Delta E \sim \frac{\hbar}{\Delta t} = \frac{h}{2\pi \Delta t} = \boxed{2.64 \cdot 10^{-11}\ J}$.

c.) $2.64 \cdot 10^{-11}\ J = m s^2 \Rightarrow$

$$m = \frac{2.64 \cdot 10^{-11}\ J}{c^2} = \boxed{\frac{164.8\ MeV}{c^2}}$$

d.) THIS IS ON THE SAME ORDER OF MAGNITUDE AS THE OBSERVED MASS OF A PION.

PROBLEM 9

a.) YOU CAN'T SAY FOR CERTAIN WHAT MOMENTUM YOU WILL MEASURE. IT WILL BE ONE OF THE FOLLOWING MOMENTUMS THAT RESULT FROM THE GIVEN WAVE LENGTHS:

$$\underline{p_1} = \frac{h}{\lambda_1} = \boxed{6.626 \cdot 10^{-24}\ J \cdot s \cdot m^{-1}}$$

$$\underline{p_2} = \frac{h}{\lambda_2} = \boxed{6.626 \cdot 10^{-25}\ J \cdot s \cdot m^{-1}}$$

$$\underline{p_3} = \frac{h}{\lambda_3} = \boxed{\frac{1}{5} \cdot 6.626 \cdot 10^{-25}\ J \cdot s \cdot m^{-1}}$$

$$\underline{p_4} = \frac{h}{\lambda_4} = \boxed{6.626 \cdot 10^{-26}\ J \cdot s \cdot m^{-1}}$$

$$\underline{p_5} = \frac{h}{\lambda_5} = \boxed{\frac{1}{2}\ 6.626 \cdot 10^{-26}\ J \cdot s \cdot m^{-1}}$$

b.) WE ARE MOST LIKELY TO OBSERVE $\boxed{p_2}$ & LEAST LIKELY TO OBSERVE $\boxed{p_3}$.

THIS CAN BE INSPECTED DIRECTLY AS WE ARE GIVEN RELATIVE AMPLITUDES AS 2:7:1:5:3.