Name____

Physics 120 Quiz #4, May 2, 2014

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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A mass of $105kg$ is suspended from a vertically oriented tungsten wire with dimensions $1mm \times 2mm \times 0.8m$ and the long axis of the tungsten wire is the vertical direction. The mass stretches the piece of tungsten wire by $1mm$ in the vertical direction

a. If tungsten has a molar mass of $184 \frac{g}{mol}$ and a density of $19250 \frac{kg}{m^3}$, what is the diameter of an atom of tungsten?

The diameter of the tungsten atom is calculated from the density.

$$\rho = \frac{m}{V} \rightarrow V = d^3 = \frac{m}{\rho} = \frac{0.184 \frac{kg}{mol} \times \frac{1mol}{6.02 \times 10^{23} atom}}{19250 \frac{kg}{m^3}} \rightarrow d = 2.51 \times 10^{-10} m .$$

b. What is the overall stiffness of the tungsten wire?

The stiffness is calculated by applying the momentum-principle to the situation. Here we have a static situation and taking the positive y-direction pointing along the vertical axis of the wire we have, $\frac{d\vec{p}}{dt} = \vec{F}_{net} \rightarrow \langle 0,0,0 \rangle = \langle 0, ky - mg, 0 \rangle \rightarrow k_{wire} = \frac{mg}{y} = \frac{105kg \times 9.8 \frac{m}{s^2}}{1 \times 10^{-3} m} = 1.03 \times 10^6 \frac{N}{m}$.

c. What is the stiffness of an interatomic bond in the tungsten wire?

To calculate the stiffness of an interatomic bond in tungsten, we need to know how many side-by-side chains of atoms we have. We have $N' = \frac{A}{d^2} = \frac{1\times10^{-3}m \times 2\times10^{-3}m}{\left(2.51\times10^{-10}m\right)^2} = 3.17\times10^{13}$. We also need to know the number of interatomic bonds in a single strand of atoms. We find $N = \frac{L}{d} = \frac{0.8m}{2.51\times10^{-10}m} = 3.19\times10^{9}$. The stiffness of the interatomic bond comes from examining a chain of springs in series, $\frac{1}{k_{chain}} = \frac{N}{k_{IAB,W}}$, where the stiffness of a chain of atoms is related to the number of side-by-side chains we have of springs in parallel, $k_{wire} = N'k_{chain}$.
Putting the last two results together we have

$$k_{IAB,W} = \left(\frac{N}{N'}\right)k_{wire} = \left(\frac{3.19\times10^{9}}{3.17\times10^{13}}\right)\times1.03\times10^{6}\,\tfrac{N}{m} = 103.7\,\tfrac{N}{m}.$$

d. What is Young's modulus for tungsten?

Young's modulus is given by $Y = \frac{k_{IAB}}{d} = \frac{103.6\,\frac{N}{m}}{2.51\times10^{-10}m} = 4.13\times10^{11}\,\frac{N}{m^2}$.

Physics 120 Equation Sheet

$\vec{r} = \langle r_x, r_y, r_z \rangle = |\vec{r}| \cdot \hat{r}$

magnitude of a vector : $r = |\vec{r}| = \sqrt{r_x^2 + r_y^2 + r_z^2}$

unit vector : $\hat{r} = \dfrac{\vec{r}}{|\vec{r}|}$

$\vec{v} = \dfrac{\Delta \vec{r}}{\Delta t}; \; \vec{v}_{avg} = \dfrac{\vec{v}_i + \vec{v}_f}{2}$

$\vec{r}_f = \vec{r}_i + \vec{v}_{avg} \Delta t$

$\vec{F}_{net} = \dfrac{\Delta \vec{p}}{\Delta t}$

$\vec{p}_f = \vec{p}_i + \vec{F}_{net} \Delta t$

$\vec{r}_f = \vec{r}_i + \vec{v}_i \Delta t + \dfrac{\vec{F}_{net}}{2m} (\Delta t)^2$

$\vec{F}_G = -\dfrac{G M_1 M_2}{r^2} \hat{r}$

$\vec{F}_g \sim m\vec{g}$

Constants:

$g = 9.8 \frac{m}{s^2}$

$G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$

$m_e = 9.11 \times 10^{-31} kg$

$m_p = 1.67 \times 10^{-27} kg$

$m_E = 6 \times 10^{24} kg$

$R_E = 6.4 \times 10^{6} m$

$N_A = 6.02 \times 10^{23}$

$\dfrac{d\vec{p}}{dt} = \vec{F}_{net}$

$\vec{F}_s = -k\vec{s}$

$F_{fr} = \mu F_N$

$k_{parallel} = \sum_{i=1}^{N} k_i$

$\dfrac{1}{k_{series}} = \sum_{i=1}^{N} \dfrac{1}{k_i}$

$\rho = \dfrac{m}{V}$

$Y = \dfrac{k_{IAB}}{d}$