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Physics 120 Quiz #3, February 3, 2012

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

1. Consider a gold wire that is suspended from the ceiling with dimensions *1cm by 1cm by 1m*. A mass of *10kg* is suspended from the wire stretching it by *12.6μm*.

   a. What is the interatomic spacing (d_{IAB}) between the gold atoms in the wire? (Hints: Assume that you have a *1cm*^{3} volume to do the calculation, the density of gold is *19300 kg/m*^{3} and the molar mass of gold is *0.197 kg/mol*.

   Assuming a 1m^3 volume the total mass of gold (ρ_{Al} = 19300 kg/m^3) is 19300kg. The number of atoms in this mass is given by

   $$\tfrac{\#\,atoms}{volume} = M_T \times m \times N_A = 19300kg \times \frac{1mole}{0.197kg} \times 6.02 \times 10^{23} = 5.9 \times 10^{28}\,\tfrac{atoms}{volume},$$ where the molar mass of gold is m = *197g/mol*. Then the number of atoms on a side of length L = *1m*, is the cubed root of the number of atoms in the volume. Thus the number of atoms on a side is $N\,\tfrac{atoms}{side} = \sqrt[3]{5.9 \times 10^{28}} = 3.89 \times 10^{9}\,\tfrac{atoms}{side}$. Lastly, in the side of length L = *1m*, there are *N(atoms/side)* each spaced by d_{IAB}. Thus the length of an interatomic bond is

   $$L = N \times d_{IAB} \rightarrow d_{IAB} = \frac{L}{N} = \frac{1m}{3.89 \times 10^{9}} = 2.57 \times 10^{-10}\,m.$$

   b. What is the mass of a single atom of gold?

   $$m_{atom} = \frac{0.197kg}{1mol} \times \frac{1mol}{6.02 \times 10^{23}\,atoms} = 3.27 \times 10^{-25}\,kg$$

   c. What is Young's modulus for gold?

   $$Stress = Y \times Strain \rightarrow Y = \frac{Stress}{Strain} = \frac{FL}{A_{wire}\Delta L} = \frac{mgL}{A_{wire}\Delta L}$$

   $$Y = \frac{10kg \times 9.8\,\tfrac{m}{s^2} \times 1m}{(0.01m)^2 \times 12.6 \times 10^{-6}m} = 7.8 \times 10^{10}\,\tfrac{N}{m^2}$$

   d. What is the speed of sound in gold?

   $$v_s = \sqrt{\frac{k_{IAB}}{m_{atom}}}d_{IAB} = \sqrt{\frac{Y d_{IAB}^3}{m_{atom}}} = \sqrt{\frac{7.8 \times 10^{10}\,\tfrac{N}{m^2} \times \left(2.6 \times 10^{-10}m\right)^3}{3.27 \times 10^{-25}m}} = 2048\,\tfrac{m}{s}$$

Useful formulas:

$\vec{p} = \gamma m\vec{v}$

$k_{eff,parallel} = n_{parallel} k_{individual}$

$\gamma = \dfrac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

$k_{eff,series} = \dfrac{k_{individual}}{n_{series}}$

$\vec{v}_{avg} = \dfrac{\vec{v}_i + \vec{v}_f}{2}$

$stress = Ystrain \rightarrow \dfrac{F}{A} = Y\dfrac{\Delta L}{L}$

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

$v_s = \sqrt{\dfrac{k_{IAB}}{m_{atom}}} d$

$\vec{F}_{gravity} = \dfrac{GM_1M_2}{r_{12}^2}\hat{r}_{12}$

$k_{IAB} = Yd$

$\vec{F}_{spring} = -k\vec{s}; \quad \vec{s} = (L - L_o)\hat{s}$

$W = \int \vec{F} \cdot d\vec{r} = \Delta KE = -\Delta U$

$U_g = -\dfrac{GM_1M_2}{r}$

$U_g = mgy$

$U_s = \dfrac{1}{2}ks^2$

$KE = \dfrac{1}{2}mv^2$

$KE = (\gamma - 1)mc^2$

Momentum Principle:

$$\vec{p}_f = \vec{p}_i + \vec{F}_{net}\Delta t; \quad \Delta t = \text{large}$$

$$\vec{p}_f = \vec{p}_i + \vec{F}_{net}dt; \quad dt = \frac{\Delta t}{n} = \text{small}$$

Position-update:

$$\vec{r}_f = \vec{r}_i + \vec{v}_{avg}\Delta t = \vec{r}_i + \frac{\vec{p}}{m\sqrt{1 + \frac{p^2}{m^2c^2}}}\Delta t; \quad \Delta t = \text{large}$$

$$\vec{r}_f = \vec{r}_i + \vec{v}_f dt; \quad dt = \frac{\Delta t}{n} = \text{small}$$

$\Delta E = W = \Delta U_g + \Delta U_s + \Delta KE$

Energy principle:

Geometry /Algebra

Circles	*Triangles*	*Spheres*
$C = 2\pi r$	$A = \frac{1}{2}bh$	$A = 4\pi r^2$
$A = \pi r^2$		$V = \frac{4}{3}\pi r^3$

Quadratic equation: $ax^2 + bx + c = 0$,

whose solutions are given by: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Vectors

magnitude of a vector: $|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$

writing a vector: $\vec{a} = \langle a_x, a_y, a_z \rangle = |\vec{a}|\hat{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$

Useful Constants

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

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

$1e = 1.6 \times 10^{-19} C$

$k = \dfrac{1}{4\pi\varepsilon_o} = 9 \times 10^9 \frac{C^2}{Nm^2}$

$\varepsilon_o = 8.85 \times 10^{-12} \frac{Nm^2}{C^2}$

$1eV = 1.6 \times 10^{-19} J$

$\mu_o = 4\pi \times 10^{-7} \frac{Tm}{A}$

$c = 3 \times 10^8 \frac{m}{s}$

$h = 6.63 \times 10^{-34} Js$

$m_e = 9.11 \times 10^{-31} kg = \dfrac{0.511 MeV}{c^2}$

$m_p = 1.67 \times 10^{-27} kg = \dfrac{937.1 MeV}{c^2}$

$m_n = 1.69 \times 10^{-27} kg = \dfrac{948.3 MeV}{c^2}$

$1amu = 1.66 \times 10^{-27} kg = \dfrac{931.5 MeV}{c^2}$

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

$Ax^2 + Bx + C = 0 \rightarrow x = \dfrac{-B \pm \sqrt{B^2 - 4AC}}{2A}$