Name____

Physics 110 Quiz #7, November 15, 2019

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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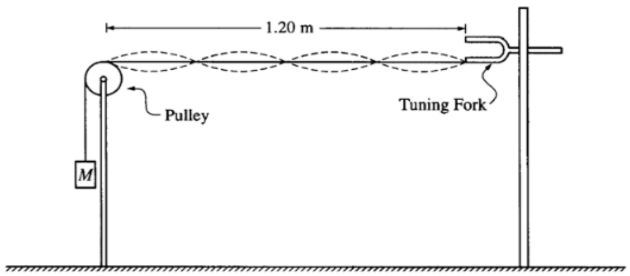
The arrangement shown below is used to study standing waves. When struck, the tuning fork oscillates at a fixed frequency f. Different masses can be suspended from the end of a steel cable (of constant linear mass density $\mu = 0.0039\frac{kg}{m}$) to generate various standing wave patterns. The length of string between the tuning fork and the pulley has a fixed length $L = 1.20m$ and when masses of either $16kg$ or $25kg$ are suspended, standing waves are produced. No standing waves are produced for masses between these two values.



https://www.npsd.k12.nj.us/cms/lib04/NJ01001216/Centricity/Domain/473/AP%20Physics%20Wave%20Problems.pdf

a. How many standing waves (closed loops) are produced when the $25kg$ mass is suspended? That is, what value of n corresponds to a mass of $25kg$? Note: the figure above is just for showing the setup of the situation. It may or may not represent the actual number of loops produced for the problem.

$$f = \frac{v_n}{\lambda_n} = \frac{n}{2x}\sqrt{\frac{F_{T,n}}{\mu}} = \frac{n}{2x}\sqrt{\frac{m_n g}{\mu}} = \frac{n+1}{2x}\sqrt{\frac{m_{n+1}g}{\mu}}$$

$$f = \frac{n}{2x}\sqrt{\frac{m_n g}{\mu}} = \frac{n+1}{2x}\sqrt{\frac{m_{n+1}g}{\mu}}$$

$$(n+1)\sqrt{m_{n+1}} = n\sqrt{m_n}$$

$$4n + 4 = 5n$$

$$n = 4$$

b. What is the single frequency f at which the tuning fork oscillates?

$$f = \frac{n}{2x}\sqrt{\frac{m_n g}{\mu}} = \left(\frac{4}{2\times 1.2m}\right)\sqrt{\frac{25kg \times 9.8\frac{m}{s^2}}{0.0039\frac{kg}{m}}} = 418s^{-1}$$

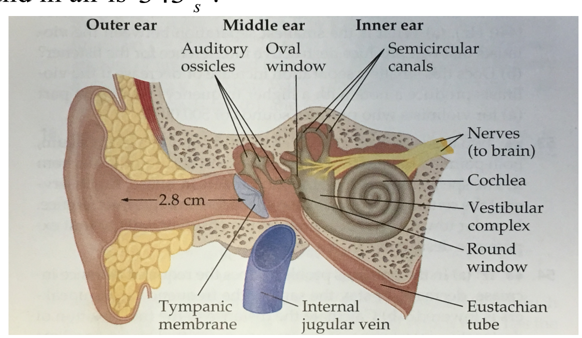
c. What is the largest mass that can be suspended and still observe standing waves?

From above, as mass increases the number of loops decreases. So for the largest mass we have the smallest number of standing loops, or $n=1$.

$$f=\frac{n}{2x}\sqrt{\frac{m_n g}{\mu}}\rightarrow m_{n=1}=\frac{4x^2 f^2\mu}{g}=\frac{4\left(1.2m\right)^2\left(418s^{-1}\right)^2\left(0.0039\frac{kg}{m}\right)}{9.8\frac{m}{s^2}}=400.5kg$$

d. The human ear canal is much like a pipe that is closed at one end (at the tympanic membrane, or the eardrum). A typical human ear has a canal length of about $2.8cm$. What is the fundamental frequency of the ear canal? The velocity of sound in air is $343\frac{m}{s}$.

$$f_1=\frac{v}{4L}=\frac{343\frac{m}{s}}{4\times 0.028m}=3063s^{-1}$$



Physics, by James Walker. Chapter 14, p. 458, Prentice Hall, 2002

e. Without adequate ear protection, damage to the delicate structures in the ear can occur. Suppose that you are at a concert where the intensity level of sound is $120dB$. By what factor does the sound intensity at a concert compare to say just normal conversational talking. Talking has an intensity level of about $60dB$.

$$\beta=10\log\left(\frac{I}{I_0}\right)\rightarrow I=I_0 10^{\frac{\beta}{10}}$$

$$\frac{I_{concert}}{I_{talking}}=\frac{I_0 10^{\frac{\beta_{concert}}{10}}}{I_0 10^{\frac{\beta_{talking}}{10}}}=10^{\frac{\beta_{concert}}{10}-\frac{\beta_{talking}}{10}}=10^{\frac{120}{10}-\frac{60}{10}}=10^6$$

Physics 110 Formulas

Equations of Motion

displacement: $\begin{cases} x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2 \\ y_f = y_i + v_{iy}t + \frac{1}{2}a_y t^2 \end{cases}$

velocity: $\begin{cases} v_{fx} = v_{ix} + a_x t \\ v_{fy} = v_{iy} + a_y t \end{cases}$

time-independent: $\begin{cases} v_{fx}^2 = v_{ix}^2 + 2a_x \Delta x \\ v_{fy}^2 = v_{iy}^2 + 2a_y \Delta y \end{cases}$

Uniform Circular Motion

$F_r = ma_r = m\frac{v^2}{r}; \quad a_r = \frac{v^2}{r}$

$v = \frac{2\pi r}{T}$

$F_G = G\frac{m_1 m_2}{r^2}$

Geometry /Algebra

Circles — $C = 2\pi r$, $A = \pi r^2$

Triangles — $A = \frac{1}{2}bh$

Spheres — $A = 4\pi r^2$, $V = \frac{4}{3}\pi r^3$

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

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

Vectors

magnitude of a vector: $v = |\vec{v}| = \sqrt{v_x^{\,2} + v_y^{\,2}}$

direction of a vector: $\phi = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

Useful Constants

$g = 9.8\, m/s^2 \qquad G = 6.67\times10^{-11}\, Nm^2/kg^2$

$N_A = 6.02\times10^{23}\, atoms/mole \qquad k_B = 1.38\times10^{-23}\, J/K$

$\sigma = 5.67\times10^{-8}\, W/m^2K^4 \qquad v_{sound} = 343\, m/s$

Linear Momentum/Forces

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

$\vec{p}_f = \vec{p}_i + \vec{F}\cdot dt$

$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$

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

$|\vec{F}_{fr}| = \mu |\vec{F}_N|$

Work/Energy

$K_T = \frac{1}{2}mv^2$

$K_R = \frac{1}{2}I\omega^2$

$U_g = mgh$

$U_S = \frac{1}{2}kx^2$

$W_T = F\Delta x \mathrm{Cos}\theta = \Delta K_T$

$W_R = \tau\theta = \Delta K_R$

$W_{net} = W_R + W_T = \Delta K_R + \Delta K_T$

$\Delta K_R + \Delta K_T + \Delta U_g + \Delta U_S = \Delta E_{system} = 0$

$\Delta K_R + \Delta K_T + \Delta U_g + \Delta U_S = \Delta E_{system} = W_{fr} = -F_{fr}\Delta x$

Rotational Motion

$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$

$\omega_f = \omega_i + \alpha t$

$\omega^2{}_f = \omega^2{}_i + 2\alpha\Delta\theta$

$\tau = I\alpha = rF$

$L = I\omega$

$L_f = L_i + \tau\Delta t$

$\Delta s = r\Delta\theta: \; v = r\omega: \; a_t = r\alpha$

$a_r = r\omega^2$

Fluids

$\rho = \frac{M}{V}$

$P = \frac{F}{A}$

$P_d = P_0 + \rho g d$

$F_B = \rho g V$

$A_1 v_1 = A_2 v_2$

$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$

$P_1 - P_2 = \Delta K_T + \Delta U_g = \left(\frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2\right) + \left(\rho g y_2 - \rho g y_1\right)$

Simple Harmonic Motion/Waves

$\omega = 2\pi f = \frac{2\pi}{T}$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$v = \pm\sqrt{\frac{k}{m}}A\left(1 - \frac{x^2}{A^2}\right)^{\frac{1}{2}}$

$x(t) = \begin{cases} x_{max}\sin\left(\frac{2\pi t}{T}\right) \\ x_{max}\cos\left(\frac{2\pi t}{T}\right) \end{cases}$

$v(t) = \begin{cases} x_{max}\sqrt{\frac{k}{m}}\cos\left(\frac{2\pi t}{T}\right) = v_{max}\cos\left(\frac{2\pi t}{T}\right) \\ -x_{max}\sqrt{\frac{k}{m}}\sin\left(\frac{2\pi t}{T}\right) = -v_{max}\sin\left(\frac{2\pi t}{T}\right) \end{cases}$

$a(t) = \begin{cases} -x_{max}\frac{k}{m}\sin\left(\frac{2\pi t}{T}\right) = -a_{max}\sin\left(\frac{2\pi t}{T}\right) \\ -x_{max}\frac{k}{m}\cos\left(\frac{2\pi t}{T}\right) = -a_{max}\cos\left(\frac{2\pi t}{T}\right) \end{cases}$

$v = f\lambda = \sqrt{\frac{F_T}{\mu}}$

$f_n = nf_1 = n\frac{v}{2L}$

$I = 2\pi^2 f^2 \rho v x_{max}^2$

Sound

$v = f\lambda = (331 + 0.6T)\frac{m}{s}$

$\beta = 10\log\frac{I}{I_0}; \quad I_o = 1\times10^{-12}\frac{W}{m^2}$

$f_n = nf_1 = n\frac{v}{2L}; \; f_n = nf_1 = n\frac{v}{4L}$