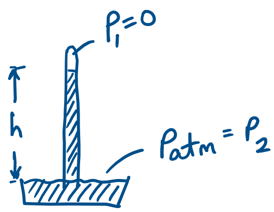
Solutions for PHYS 117 2021 Regular Midterm Exam

CONCEPT QUESTIONS

2. On a planet where the atmospheric pressure is twice as much as on the Earth and the acceleration due to gravity is four times as much as on the Earth, what will be the height of the column in a mercury barometer, if the height of the column in a mercury barometer on Earth is 760 mm?

   (A) 1520 mm (B) 95 mm (C) 380 mm (D) 3040 mm (E) 760 mm



$$P_2 = P_1 + \rho g h$$

$$P_2 = \rho g h \quad \text{since } P_1 = 0$$

$$P_{2E} = \rho g_E h_E$$

$$\Downarrow$$

$$\rho = \frac{P_{2E}}{g_E h_E}$$

$$P_{2P} = \rho g_P h_P$$

$$\Downarrow$$

$$h_P = \frac{P_{2P}}{\rho g_P}$$

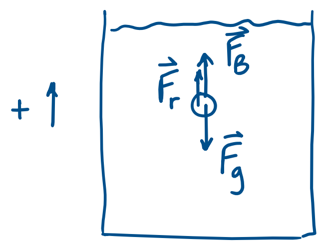
$$h_P = \frac{P_{2P}}{g_P} \cdot \frac{g_E h_E}{P_{2E}}$$

Given: $P_{2P} = 2P_{2E}$ and $g_P = 4g_E$ and $h_E = 760\text{ mm}$

$$h_P = \frac{2P_{2E}}{4g_E} \cdot \frac{g_E(760\text{ mm})}{P_{2E}} = \frac{760\text{ mm}}{2} = 380\text{ mm}$$

3. For an object moving downwards in a viscous medium, which one of the following statements is true regarding the buoyant force, F_B, the resistive frictional (drag) force, F_r, and the gravitational force, F_g, acting on the object?

   (A) F_B UP, F_r DOWN, and these two forces add to zero
   (B) F_B UP, F_r DOWN, F_g DOWN
   (C) F_B UP, F_r UP, F_g DOWN
   (D) F_B UP, F_g DOWN, and these two forces add to zero
   (E) F_r UP, F_g DOWN, and these two forces add to zero



$\vec{F}_B$: UP always
$\vec{F}_g$: DOWN always
$\vec{F}_r$: opposite to direction of motion
$\therefore$ UP in this case

If terminal speed has been reached, $F_r + F_B - F_g = 0$

If terminal speed has not been reached, $F_g > F_r + F_B$

4. Which one of the following statements dealing with the deformation of solids is **TRUE**?

(A) The elastic moduli (Young's, Shear, and Bulk) all have the dimension of pressure.
(B) If a metal rod is stressed within its elastic limit, doubling the tensile stress results in the rod stretching an amount that is four times the stretch due to the original stress.
(C) If a metal rod is stressed within its elastic limit, increasing the tensile stress has no effect on the strain.
(D) Shear modulus is a measure of the change in the surface area of an object under stress.

$\frac{F}{A} = Y \frac{\Delta L}{L_o}$; $\frac{F}{A} = S \frac{\Delta x}{h}$; $\Delta P = -B \frac{\Delta V}{V}$ $\therefore$ (A) is true

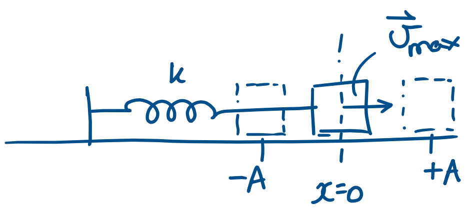
(B) is false b/c stress, $\frac{F}{A}$, is proportional to ΔL.

(C) is false b/c stress, $\frac{F}{A}$, and strain, $\frac{\Delta L}{L}$, are directly proportional

(D) is false b/c shear modulus relates to the shift of one face relative to a face that is a distance h away.

5. A block on a horizontal frictionless surface is connected to an ideal spring (spring constant k) and moves with simple harmonic motion of amplitude A. The velocity and acceleration of the block are v and a, respectively. Which one of the following expressions is correct?

- ○ At maximum displacement from equilibrium, $v = 0$ and $a = \frac{mA}{k}$ FALSE
- ○ At the equilibrium position, $v = \sqrt{\frac{kA^2}{m}}$ and $a = 0$ ✓ TRUE
- ○ At the equilibrium position, $v = 0$ and $a = 0$ X FALSE, $v = v_{max}$
- ○ At the equilibrium position, $v = \sqrt{\frac{kA}{m}}$ and $a = \frac{kA^2}{m}$ X FALSE, $a = 0$
- ○ At maximum displacement, $v = 0$ and $a = \frac{kA^2}{m}$ X FALSE, $a = -\frac{k}{m}x$



$$E_{tot} = PE_s + KE$$

$$\frac{1}{2}kA^2 = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$

At $x = A$, $v = 0$

and $a = -\frac{k}{m}A$

$$F = -kx$$

$$ma = -kx$$

$$a = -\frac{k}{m}x$$

At $x = 0$, $\cancel{\frac{1}{2}}kA^2 = \cancel{\frac{1}{2}}mv_{max}^2$

$$v_{max} = \sqrt{\frac{kA^2}{m}}$$

6. A person is standing at rest on the platform at a train station. Train 1 is stopped at the station and Train 2 is moving away from the station at a constant speed of 21.0 km/h. Each train blows its whistle at the identical frequency of 194 Hz, but the person hears beats with a frequency of 6.00 Hz. What is the frequency that the person detects for Train 2's whistle?

(A) 200 Hz (B) 188 Hz (C) 197 Hz (D) 194 Hz (E) 191 Hz

$f_b = |f_2 - f_1|$

Since Train 2 is moving away, the frequency heard by the person will be less than the whistle frequency.

$\therefore f_2 < f_1$

$\therefore f_b = f_1 - f_2 \Rightarrow f_2 = f_1 - f_b = 194\,Hz - 6\,Hz$

$f_2 = 188\,Hz$

7. A listener hears the sound from a very small spherical speaker. The power of the sound being emitted from the speaker is then increased and the listener starts walking away from the speaker. When the listener is 10 times further from the speaker than their initial distance, the power emitted by the speaker is 100 times greater than the initial power. What is the resulting change in sound intensity level between the initial and final locations of the listener?

(A) The sound intensity level has gone down by 5 dB.
(B) The sound intensity level has gone down by 10 dB.
(C) There is no change in the sound intensity level.
(D) The sound intensity level has gone up by 5 dB.
(E) The sound intensity level has gone up by 10 dB.

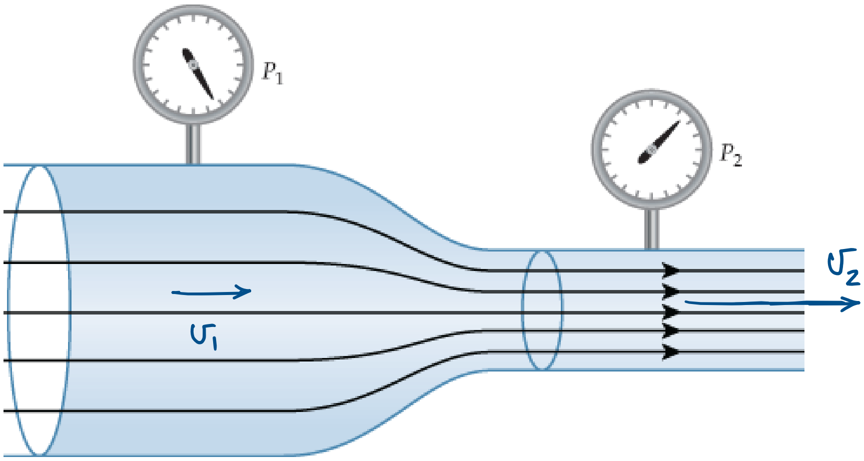
$I = \frac{P}{A}$ and $\beta = 10 \log\left(\frac{I}{I_0}\right)$

$I = \frac{P}{\pi r^2} \Rightarrow \frac{I_2}{I_1} = \frac{P_2 \pi r_1^2}{P_1 \pi r_2^2} = \frac{P_2 r_1^2}{P_1 r_2^2} = \frac{100 P_1 \cdot r_1^2}{P_1 \cdot (10 r_1)^2} = \frac{100}{100} = 1.$

no change in intensity $\Rightarrow$ no change in sound intensity level.

WORD PROBLEMS:

8. The flow of gasoline through a hose can be monitored using a Venturi tube similar to the one shown in the figure. The density of gasoline is $\rho = 7.00 \times 10^2$ kg/m^3, the inlet radius of the Venturi tube (cross-section 1) is 2.50 cm, the outlet radius (cross-section 2) is 1.70 cm, and the difference in pressure measured by the two gauges is $P_1 - P_2 = 1.70$ kPa.



Continuity Equation:

$$A_1 v_1 = A_2 v_2 \quad ①$$

Bernoulli's Principle for horizontal pipe:

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2 \quad ②$$

(a) Calculate the speed of the gasoline as it leaves the Venturi tube. 2.49 m/s
(b) Calculate the volume flow rate of the gasoline. 0.00226 m^3/s

(a) From ①, $v_1 = \dfrac{A_2 v_2}{A_1} = \left(\dfrac{\pi r_2^2}{\pi r_1^2}\right) v_2 = \left(\dfrac{r_2^2}{r_1^2}\right) v_2$

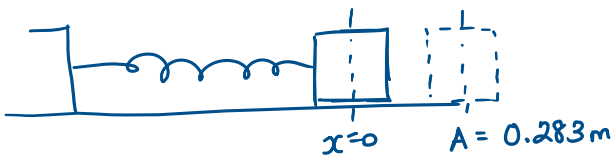
Substitute into ②: $P_1 + \tfrac{1}{2}\rho v_2^2 \left(\dfrac{r_2^2}{r_1^2}\right)^2 = P_2 + \tfrac{1}{2}\rho v_2^2$

$$P_1 - P_2 = \tfrac{1}{2}\rho v_2^2\left(1 - \left(\frac{r_2}{r_1}\right)^4\right) \Rightarrow v_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho\left(1 - \left(\frac{r_2}{r_1}\right)^4\right)}}$$

$$v_2 = \sqrt{\frac{2(1.70 \times 10^3 \text{ Pa})}{(700 \text{ kg/m}^3)\left(1 - \left(\frac{1.70 \text{ cm}}{2.50 \text{ cm}}\right)^4\right)}} = \boxed{2.49 \text{ m/s}}$$

(b) $Q = \dfrac{\Delta V}{\Delta t} = A_2 v_2 = \pi r_2^2 v_2 = \pi (1.70 \times 10^{-2} \text{ m})^2 (2.4856 \text{ m/s}) = \boxed{2.26 \times 10^{-3} \text{ m}^3\text{/s}}$

9. A block on a horizontal frictionless surface is attached to a horizontal ideal spring and oscillating with a maximum displacement from equilibrium of 0.283 m. The maximum speed of the block is 3.45 m/s. The total mechanical energy of the block-spring system is $E = 38.0$ J.
   (a) Calculate the spring constant. 949 N/m
   (b) Calculate the speed of the block when its displacement is 0.160 m. 2.85 m/s
   (c) Suppose the same system is released from rest at $x = 0.283$ m on a rough surface so that it loses 15.2 J by the time the block reaches its first turn-around point (after passing equilibrium at $x = 0$). Calculate the distance of the block from the equilibrium position at that instant. 0.219 m



$$E = PE_s + KE = 38.0\,\text{J} = \tfrac{1}{2}kA^2$$

(a) $$\frac{2E}{A^2} = k = \frac{2(38.0\,\text{J})}{(0.283\,\text{m})^2} = 948.9\,\text{N/m}$$

(b) $$E = 0 + \tfrac{1}{2}m\upsilon_{max}^2 \Rightarrow m = \frac{2E}{\upsilon_{max}^2} = \frac{2(38.0\text{ J})}{(3.45\text{ m/s})^2} = 6.385\text{ kg}$$

$$E = \tfrac{1}{2}kx^2 + \tfrac{1}{2}m\upsilon^2 \Rightarrow \sqrt{\frac{2E - kx^2}{m}} = \upsilon = 2.846\,\text{m/s}$$

(c) At turning point, $\upsilon = 0$, $E_f = E_i - E_{lost} = 38.0\,\text{J} - 15.2\,\text{J} = 22.8\,\text{J}$

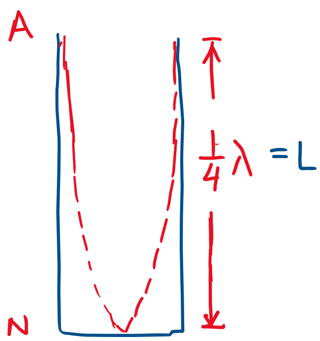
E_f is all PE_s $\Rightarrow$ $\tfrac{1}{2}kx_f^2 = E_f \Rightarrow x_f = \sqrt{\frac{2E_f}{k}} = \sqrt{\frac{2(22.8\,\text{J})}{(948.9\,\text{N/m})}} = 0.219\,\text{m}$

10. A simplified version of our voice production system considers the throat and mouth to be a tube closed at one end.

(a) Calculate the fundamental frequency (to the nearest Hz) if the effective length of the tube is 0.252 m and the air temperature is 31.0°C. The speed of sound in air at 0°C is 331 m/s. 347 Hz

(b) Assuming that the temperature dependence of the speed of sound in helium is the same as for air, determine the fundamental frequency (to the nearest Hz) if the air is replaced by helium. The speed of sound in helium at 0°C is 965 m/s. 1010 Hz

(a)



At fundamental frequency, $L = \frac{1}{4}\lambda \Rightarrow \lambda = 4L$

$$f = \frac{v}{\lambda} \quad \text{and} \quad v = (331\,\text{m/s})\sqrt{\frac{T}{273\,\text{K}}}$$

$$f = \frac{331\,\text{m/s}}{4(0.252\,\text{m})}\sqrt{\frac{273+31}{273}} = 346.5\,\text{Hz}$$

(b) $$f_{He} = \left(\frac{965\,\text{m/s}}{331\,\text{m/s}}\right) f_{air} = 1.01 \times 10^3\,\text{Hz}$$