# UNIVERSITY OF SASKATCHEWAN

**Department of Physics and Engineering Physics**

## Physics 117.3

## MIDTERM EXAM – Alternative Sitting

February 2019 Time: 90 minutes

NAME: ______________SOLUTIONS________________________ STUDENT NO.: _____________

(Last) **Please Print** (Given)

LECTURE SECTION (please check):

❑ 01 Dr. Y. Yao

❑ 02 Mr. B. Zulkoskey

**INSTRUCTIONS:**

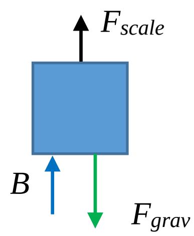
1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card and an OMR (OpScan / bubble) sheet. The test paper consists of 8 pages, including this cover page. **It is the responsibility of the student to check that the test paper is complete**.
3. Only a basic scientific calculator (e.g. Texas Instruments TI-30X series, Hewlett-Packard HP 10s or 30S) may be used. Graphing or programmable calculators, or calculators with communication capability, or calculators in smart phones are **not** allowed.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your name on the exam booklet and scratch card.
5. Enter your name and NSID on the OMR (OpScan / bubble) sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR (OpScan / bubble) sheet must all be submitted.
7. No test materials will be returned.

| QUESTION NUMBER | MAXIMUM MARKS | MARKS OBTAINED |
|---|---|---|
| A1-12 | 12 | |
| B1-4 | 8 | |
| B5-8 | 8 | |
| B9-12 | 8 | |
| B13-16 | 8 | |
| MARK | out of 36: | |

B1. The density of wood is less than the density of water. Which one of the following statements is correct for the situation of a piece of wood that is held so that it is completely submerged?

The water exerts an upward buoyant force on the piece of wood. The magnitude of this buoyant force is the weight of the volume of water that is displaced by the piece of wood. Since the piece of wood is completely submerged, the volume of water that is displaced is equal to the volume of the piece of wood.

B2. A person has a mass of 70.2 kg. When the person is completely submerged in a swimming pool and suspended from a scale, the scale reads 33.3 N. Calculate the volume of water displaced by the person.




The person is in equilibrium, so the net force on the person is zero.

$$\sum F = 0 \quad \Rightarrow \quad +B + F_{scale} - F_{grav} = 0$$

Fully submerged means that the volume of displaced water equals the total volume of the person.

$$+\rho_{water} g V_{person} + F_{scale} - m_{person} g = 0$$

$$V_{person} = \frac{m_{person} g - F_{scale}}{\rho_{water} g} = \frac{m_{person}}{\rho_{water}} - \frac{F_{scale}}{\rho_{water} g} = \frac{70.2\text{ kg}}{1.00\times 10^3\text{ kg/m}^3} - \frac{33.3\text{ N}}{(1.00\times 10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)}$$

$$\boxed{V_{person} = 6.680\times 10^{-2}\text{ m}^3}$$

B3. Assume that, when submerged, the person's body contains a residual volume of $V_R = 1.30 \times 10^{-3}$ m$^3$ of air in the lungs. Ignoring the mass of this air, calculate the average density of the tissue of this person's body.

$$\rho = \frac{m_{person}}{V_{person} - V_R} = \frac{70.2\text{ kg}}{(6.68\times 10^{-2}\text{ m}^3 - 1.30\times 10^{-3}\text{ m}^3)} = \boxed{1.072\times 10^3\text{ kg/m}^3}$$

B4. 11.75% of the person's mass is body fat. Calculate the percentage of the person's **tissue volume** that is comprised of fat-free tissue. The density of body fat is $0.900 \times 10^3$ kg/m$^3$ and the density of fat-free tissue is $1.10 \times 10^3$ kg/m$^3$.

The volume of the person's tissue is given by:

$$V_{tissue} = V_{bodyfat} + V_{non-fat}$$

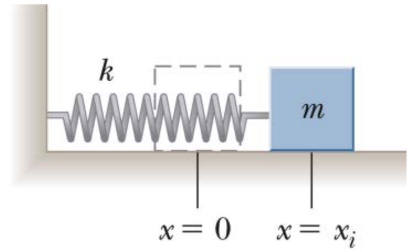
$$\frac{m_{person}}{\rho_{avg}} = \frac{m_{bodyfat}}{\rho_{bodyfat}} + V_{non-fat}$$

$$V_{non-fat} = \frac{m_{person}}{\rho_{avg}} - \frac{m_{bodyfat}}{\rho_{bodyfat}} = \frac{m_{person}}{\rho_{avg}} - \frac{\%BF \times m_{person}}{\rho_{bodyfat}} = m_{person}\left(\frac{1}{\rho_{avg}} - \frac{\%BF}{\rho_{bodyfat}}\right)$$

$$\frac{V_{non-fat}}{V_{tissue}} = \frac{m_{person}}{V_{tissue}}\left(\frac{1}{\rho_{avg}} - \frac{\%BF}{\rho_{bodyfat}}\right) = \rho_{avg}\left(\frac{1}{\rho_{avg}} - \frac{\%BF}{\rho_{bodyfat}}\right) = 1 - \frac{\%BF\,\rho_{avg}}{\rho_{bodyfat}}$$

$$\frac{V_{non-fat}}{V_{tissue}} = 1 - \frac{\%BF\,\rho_{avg}}{\rho_{bodyfat}} = 1 - \frac{(0.1175)(1.072\times10^3\ \text{kg/m}^3)}{0.900\times10^3\ \text{kg/m}^3} = 0.8600 = \boxed{86.0\%}$$

A block is attached to a spring and vibrates on a frictionless, horizontal surface with an amplitude of $x_i$ = 20.0 cm and a total energy of 0.300 J. The maximum speed of the block is 0.250 m/s.




B5. Which one of the following statements is **TRUE**?

The total energy of the system is proportional to the square of the amplitude, because when the mass is at maximum displacement its speed is zero.

$$E_{tot} = KE + PE = \tfrac{1}{2}mv^2 + \tfrac{1}{2}kx^2 = 0 + \tfrac{1}{2}kx_{\max}{}^2 = \tfrac{1}{2}kA^2$$

B6. Calculate the spring constant.

$$E_{tot} = \tfrac{1}{2}kA^2 \quad \Rightarrow \quad k = \frac{2E}{A^2} = \frac{2(0.300\text{ J})}{(0.200\text{ m})^2} = \boxed{15.0\text{ N/m}}$$

B7. Calculate the angular frequency of the oscillation of the block.

$v = -A\omega\sin(2\pi ft) \quad \Rightarrow \quad v_{\max} = A\omega$, because the maximum value of sine is 1.

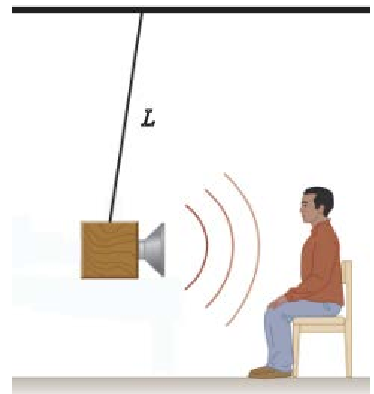
$$\omega = \frac{v_{\max}}{A} = \frac{0.250\text{ m/s}}{0.200\text{ m}} = \boxed{1.25\text{ rad/s}}$$

B8. Calculate the kinetic energy of the block when it is at a position of $x = \frac{2}{3}x_i$.

$$E_{tot} = KE + PE = KE + \tfrac{1}{2}kx^2$$

$$KE = E_{tot} - \tfrac{1}{2}kx^2 = 0.300\text{ J} - \tfrac{1}{2}(15.0\text{ N/m})[\tfrac{2}{3}(0.200\text{ m})]^2 = \boxed{0.167\text{ J}}$$

A speaker of mass 2.60 kg is suspended from a rope that is attached to the ceiling. The speaker-rope system can be considered to be a simple pendulum of length $L$ = 1.80 m. The speaker is continually producing sound of frequency 442 Hz as the speaker oscillates back and forth. The maximum height of the speaker above its equilibrium position is $h$ = 4.00 cm. A man is seated in front of the speaker, as shown in the diagram. The speed of sound is 343 m/s.




B9. At which point in the speaker's motion will the man hear the highest frequency of sound from the speaker?

The man will hear the highest frequency of sound when the speaker is passing through its equilibrium position (moving with maximum speed) and moving toward the man.

B10. Calculate the period of the speaker's motion.

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{1.80\text{ m}}{9.80\text{ m/s}^2}} = \boxed{2.69\text{ s}}$$

B11. Calculate the maximum speed of the speaker.

Ignoring any effects due to air resistance, the energy of the pendulum is constant. When the speaker is at maximum height above its equilibrium position, all the energy is gravitational potential. When the speaker is passing through the equilibrium position, the speed of the speaker is maximum.

$$mgh = \tfrac{1}{2}m\upsilon_{\text{max}}^2 \quad \Rightarrow \quad \upsilon_{\text{max}} = \sqrt{2gh} = \sqrt{2(9.80\text{ m/s}^2)(0.0400\text{ m})} = \boxed{0.8854\text{ m/s}}$$

B12. Calculate the change in the frequency of the speaker's sound, as detected by the man, as the speaker moves back and forth.

The Doppler effect occurs as the speaker moves toward and away from the man. The man hears $f_{max}$ when the speaker is moving with maximum speed toward him and he hears $f_{min}$ when the speaker is moving with maximum speed away from him. The speaker is a moving source, and the observer, the man, is at rest.

$$\Delta f = f_{o,\max} - f_{o,\min} = f_s\left(\frac{\upsilon}{\upsilon - \upsilon_s}\right) - f_s\left(\frac{\upsilon}{\upsilon + \upsilon_s}\right) = f_s\upsilon\left(\frac{1}{\upsilon - \upsilon_s} - \frac{1}{\upsilon + \upsilon_s}\right)$$

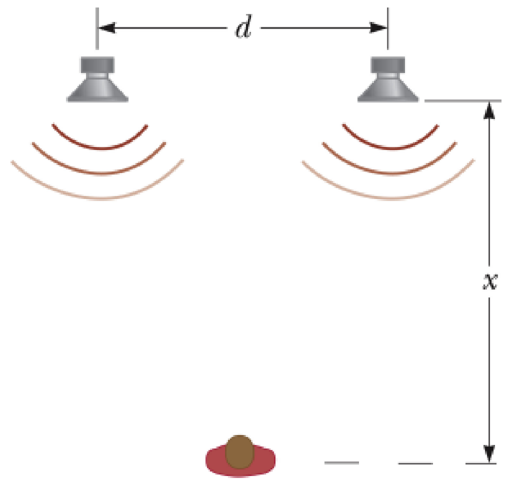
$$\Delta f = f_s\upsilon\left(\frac{\upsilon + \upsilon_s - (\upsilon - \upsilon_s)}{(\upsilon - \upsilon_s)(\upsilon + \upsilon_s)}\right) = f_s\upsilon\left(\frac{2\upsilon_s}{(\upsilon^2 - \upsilon_s{}^2)}\right) = f_s\left(\frac{2\upsilon\upsilon_s}{(\upsilon^2 - \upsilon_s{}^2)}\right)$$

$$\Delta f = (442\ \text{Hz})\left(\frac{2(343\ \text{m/s})(0.8854\ \text{m/s})}{((343\ \text{m/s})^2 - (0.8854\ \text{m/s})^2)}\right) = \boxed{2.28\ \text{Hz}}$$

B13. Two speakers are producing identical in-phase sound waves of equal power $P$ and wavelength $\lambda$. Choose the phrase that best completes the following sentence: "If you are a distance $r$ from one speaker and a distance $r - \lambda$ from the other speaker, then…

you are at a position of constructive interference and the intensity of the sound due to the speaker at a distance $r - \lambda$ is greater than the intensity of the sound due to the other speaker." The path length difference is an integer number of wavelengths, therefore constructive interference. You will hear higher intensity of sound from the speaker that is closer to you.

Two speakers, separated by a distance $d$ = 0.700 m, are driven by the same oscillator. A person is standing a distance $x$ = 1.55 m from the midpoint of the line joining the two speakers, as shown in the figure. The person is the same distance from each speaker.




B14. The power output of each speaker is the same. If the sound intensity level at the person's position is 82.6 dB, calculate the sound intensity due to **one** speaker at the person's location.

Since the power output of each speaker is the same and the person is the same distance from each speaker, each speaker is producing the same intensity of sound at the person's location. Let *I* represent the intensity due to each speaker.

$$\beta_{tot} = 10\log\left(\frac{2I}{I_0}\right) \Rightarrow 10^{\beta_{tot}/10} = \frac{2I}{I_0} \Rightarrow \frac{I_0 \times 10^{\beta_{tot}/10}}{2} = I$$

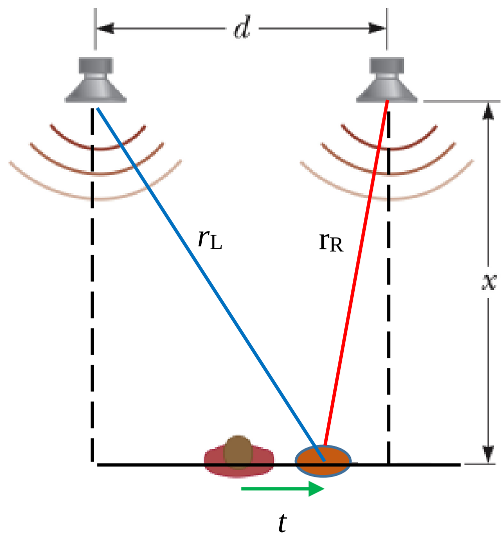
$$I = \frac{1.00\times10^{-12}\ \text{W/m}^2 \times 10^{82.6/10}}{2} = \boxed{9.10\times10^{-5}\ \text{W/m}^2}$$

B15. Calculate the speed of the sound produced by the speakers. The air temperature is 25.0°C.

$$\upsilon = (331\ \text{m/s})\sqrt{\frac{273+25.0}{273}} = \boxed{345.8\ \text{m/s}}$$

B16. The person now moves to the right, a distance of 0.246 m along the dashed line that is parallel to a line joining the two speakers, and reaches the first position of destructive interference. Calculate the frequency of sound that the speakers are producing.

The person must move until the difference in distance from the two speakers is one-half the wavelength of the sound being emitted. Let *t* be the distance that the person moves.




$$r_L - r_R = \tfrac{1}{2}\lambda$$

$$\sqrt{x^2 + (\tfrac{1}{2}d + t)^2} - \sqrt{x^2 + (\tfrac{1}{2}d - t)^2} = \tfrac{1}{2}\lambda = \frac{\upsilon}{2f}$$

$$f = \frac{\upsilon}{2\left[\sqrt{x^2 + (\tfrac{1}{2}d + t)^2} - \sqrt{x^2 + (\tfrac{1}{2}d - t)^2}\right]}$$

$$f = \frac{345.8 \text{ m/s}}{2\left[\sqrt{(1.55 \text{ m})^2 + (0.350 \text{ m} + 0.246 \text{ m})^2} - \sqrt{1.55 \text{ m}^2 + (0.350 \text{ m} - 0.246)^2}\right]}$$

$$f = \frac{345.8 \text{ m/s}}{2[1.6606 \text{ m} - 1.5535 \text{ m}]} = 1.61 \times 10^3 \text{ Hz} = \boxed{1.61 \text{ kHz}}$$

***END OF EXAMINATION***