UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM EXAM – Regular Sitting

February 14, 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:	

PART A

For each of the following questions in Part A, enter the most appropriate response on the OMR (OpScan / bubble) sheet. Use the exam booklet for your rough work.

A1. Let h be the depth below the surface of the ocean at which the absolute pressure is twice atmospheric pressure (i.e. $2P_{\text{atm}}$). The pressure at a depth of $2h$ below the surface of the ocean is

(A) $2.5P_{\text{atm}}$ (B) $3P_{\text{atm}}$ (C) $4P_{\text{atm}}$ (D) $5P_{\text{atm}}$ (E) $9P_{\text{atm}}$

> Recall that the absolute pressure at a depth of h is $P_h = P_{atm} + \rho gh$. It is given that $P_h = 2P_{atm}$, which means that $\rho gh = P_{atm}$. At a depth of $2h$, the absolute pressure is $P_{2h} = P_{atm} + \rho g2h = P_{atm} + 2\rho gh = P_{atm} + 2P_{atm} = 3P_{atm}$ (B)

A2. Two objects of identical volume are placed in a container that is filled with an unknown liquid. One object floats and the other sinks to the bottom. Which one of the following is a true statement concerning the masses of the objects?

(A) Both objects have the same mass.
(B) The floating object's mass is greater than the mass of the object that sinks.
(C) The floating object's mass is less than the mass of the object that sinks.
(D) Nothing can be said about the masses without knowing the densities of the objects.
(E) Nothing can be said about the masses without knowing the density of the unknown liquid.

> The floating object displaces less liquid than the one that sinks. Therefore the buoyant force on the floating object is less than the buoyant force on the object that sinks. The buoyant force on the object that floats has the same magnitude as the object`s weight. The buoyant force on the object that sinks is less than the weight of this object. Therefore, the floating object`s weight (and mass) is less than the weight (and mass) of the object that sinks. (C)

A3. An ideal incompressible fluid is flowing through a horizontal pipe with a constriction. One section of the pipe has a radius of R and the other section of the pipe has a radius of ½ R. Which one of the following statements is **<u>TRUE</u>**?

(A) Both the flow speed and pressure are higher at the larger end.
(B) The flow speed is the same throughout the pipe but the pressure is lower at the larger end.
(C) The flow speed at the larger end is half the flow speed at the narrower end.
(D) The flow speed at the narrower end is four times the flow speed at the larger end.
(E) The pressure is the same throughout the pipe.

> The continuity equation applies and, since it is an ideal fluid, Bernoulli`s equation also applies. In the constricted region the cross-sectional area is ¼ of the cross-sectional area in the larger region (cross-sectional area depends on the square of the radius). Since the product of flow speed and cross-sectional area is constant (continuity equation), the flow speed is higher by a factor of 4 in the constricted region. (D)

A4. A spherical object of radius r falls with a terminal speed υ through a fluid with viscosity η. Which one of the following statements is **TRUE**?

(A) The net force on the object has magnitude mg.
(B) The object has an acceleration of magnitude g.
(C) The viscous drag force causes the net force on the object to be zero.
(D) The viscous drag force is in the same direction as the force of gravity on the object.
(E) The viscous drag force is the only force acting on the object.

The forces acting on the object are its weight (down), the buoyant force (up), and the viscous drag force (up, opposite to the object's motion). Since the object is falling with a terminal speed, it is not accelerating and therefore the net force on the object is zero. Since the weight and buoyant forces have constant values, it is the viscous drag force that causes the net force on the object to be zero. (C)

A5. If one could transport a simple pendulum of constant length from the Earth's surface to the Moon's, where the acceleration due to gravity is one-sixth (1/6) of that on Earth, by what factor would the pendulum frequency be changed?

(A) $f_M \approx 6f_E$ (B) $f_M \approx 2.5f_E$ (C) $f_M \approx 0.41f_E$ (D) $f_M \approx 0.17f_E$ (E) $f_M = 3.5f_E$

$$T = 2\pi\sqrt{\frac{L}{g}} \quad \Rightarrow \quad f = \frac{1}{2\pi}\sqrt{\frac{g}{L}} \quad \text{so } f_E = \frac{1}{2\pi}\sqrt{\frac{g_E}{L}}$$

$$f_M = \frac{1}{2\pi}\sqrt{\frac{g_M}{L}} = \frac{1}{2\pi}\sqrt{\frac{(1/6)g_E}{L}} = \frac{1}{2\pi}\sqrt{\frac{1}{6}}\sqrt{\frac{g_E}{L}} = \sqrt{\frac{1}{6}}\frac{1}{2\pi}\sqrt{\frac{g_E}{L}} = 0.41 f_E \quad \text{(C)}$$

A6. Consider two rigid bars. The shear modulus of bar 1 is larger than the shear modulus of bar 2. Which one of the following statements **must** be **TRUE**?

(A) Bar 1 is longer than bar 2.
(B) Bar 1 has a larger surface area than bar 2.
(C) Bar 1 is heavier than bar 2.
(D) The net force acting on bar 1 is larger than the net force acting on bar 2.
(E) Bar 1 and bar 2 are made of different materials.

Shear modulus is a property of the material of the bars, so if the shear modulus values are different, then the bars are made of different materials. (E)

A7. A horizontal pipe is replaced by one of the same length but half of the radius. If the pressure difference between the ends of the pipe is doubled, by what factor is the volume flow rate of a viscous liquid through the new pipe changed from the volume flow rate through the original pipe?

(A) $Q_2 = \frac{1}{16} Q_1$ (B) $Q_2 = \frac{1}{8} Q_1$ (C) $Q_2 = \frac{1}{2} Q_1$
(D) $Q_2 = Q_1$ (E) $Q_2 = 2Q_1$

It is given that the liquid is viscous, so Poiseuille's Law applies.

$$\left(\frac{\Delta V}{\Delta t}\right)_1 = Q_1 = \frac{\pi R_1^{\,4}(P_1 - P_2)_1}{8\eta L}$$

$$\left(\frac{\Delta V}{\Delta t}\right)_2 = Q_2 = \frac{\pi R_2^{\,4}(P_1 - P_2)_2}{8\eta L} = \frac{\pi\left(\frac{1}{2}R_1\right)^4 2(P_1 - P_2)_1}{8\eta L} = 2\left(\frac{1}{2}\right)^4 \frac{\pi R_1^{\,4}(P_1 - P_2)_1}{8\eta L} = \frac{1}{8}Q_1 \quad \text{(B)}$$

A8. A source is producing sound energy at a constant rate. You detect a sound intensity level of 60.0 dB. If you reduce your distance from the sound source by a factor of 2, how does the sound intensity level at your new location compare to the sound intensity level at your original location?

(A) The sound intensity level doubles.
(B) The sound intensity level increases by a factor of 4.
(C) The sound intensity level increases by a factor of 10.
(D) The sound intensity level increases by a factor of 100.
(E) The sound intensity level increases by a factor less than 2.

Reducing the distance from the source by a factor of 2 means that the intensity increases by a factor of 4. Recall that intensity **level** (in dB), increases by 10 dB for every factor of 10 increase in intensity. Since the intensity has increased by less than a factor of 10, the intensity **level** will increase by less than 10 dB. That is, the new intensity level will be less than 70 dB. (E)

A9. The speed of a wave in a stretched string is initially 50 m/s. What will be the new wave speed if the tension in the string is increased by 18%?

(A) 50 m/s (B) 54 m/s (C) 21 m/s (D) 59 m/s (E) 45 m/s

$$v_1 = \sqrt{\frac{F_1}{\mu}} \;;\quad v_2 = \sqrt{\frac{F_2}{\mu}} = \sqrt{\frac{1.18F_1}{\mu}} = \sqrt{1.18}\sqrt{\frac{F_1}{\mu}} = \sqrt{1.18}\,v_1 = \sqrt{1.18}(50.0 \text{ m/s}) = 54 \text{ m/s} \quad \text{(B)}$$

A10. Given that the strings of a guitar are the same length, is it possible for the strings to have the same tension but have different fundamental frequencies of vibration?

(A) Yes, and the lower the desired fundamental frequency, the smaller the required linear mass density of the string.
(B) Yes, and the lower the desired fundamental frequency, the larger the required linear mass density of the string.
(C) No, this is not possible because all strings at the same tension must have the same fundamental frequency.
(D) Yes, and the higher the desired fundamental frequency, the larger the required linear mass density of the string.
(E) No, this is not possible because all strings of the same length must have the same fundamental frequency.

As shown in the previous question, the speed of the waves on the strings depends on the tension and the linear mass density. The fundamental frequency depends on speed and wavelength, and the fundamental wavelength depends on the length of the string. Since the strings are the same length and have the same tension, the only variable is the linear mass density. Since the wave speed, and therefore fundamental frequency, depends on the inverse square root of the linear mass density, to obtain a lower desired frequency, the linear mass density must be larger. (B)

A11. The standing wave pattern in a pipe is NANA, where N stands for node and A for antinode. Which one of the following statements is **TRUE**?

(A) The pipe is open at both ends.
(B) The pipe is closed at both ends.
(C) The pipe is open at one end and closed at the other end.
(D) The pipe is vibrating at the fundamental frequency.
(E) The pipe is vibrating at the second harmonic frequency.

There will be a displacement node at a closed end and a displacement antinode at an open end, so this pipe is open at one end and closed at the other end. The fundamental mode has a pattern of NA ($L = \frac{1}{4}\lambda$) for this type of pipe, and the next possible mode is NANA, which corresponds to $L = \frac{3}{4}\lambda$, the third harmonic. (C)

A12. Which one of the following statements is true regarding electromagnetic waves traveling through a vacuum?

(A) All waves have the same wavelength.
(B) All waves have the same frequency.
(C) The electric and magnetic fields associated with the waves are parallel to each other and perpendicular to the direction of wave propagation.
(D) The electric and magnetic fields associated with the waves are perpendicular to each other and to the direction of wave propagation.
(E) The speed of the waves depends on their frequency.

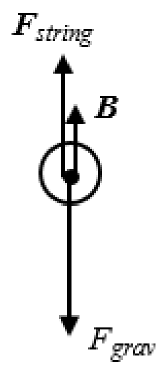
All EM waves have the same speed in a vacuum, but the frequencies and wavelengths can have a wide range of values. (D) is correct.

A wooden block of mass 3.00 kg floats in water, and a steel object of mass 0.255 kg is attached to the bottom of the block by a massless string. The steel object is not in contact with the bottom of the container. The density of steel is 8.05×10^3 kg/m^3. The density of wood is 0.750×10^3 kg/m^3. The density of water is 1.00×10^3 kg/m^3.

B1. Which one of the following statements is **TRUE**?

The buoyant force on the wooden block is equal to the weight of the volume of water it displaces.

B2. Which one of the following is the correct free-body diagram for the steel object?



B3. Calculate the magnitude of the buoyant force on the steel object.

The buoyant force is the weight of the volume of fluid that has been displaced by the object. Since the steel object is completely submerged, the volume of displaced fluid is the volume of the object.

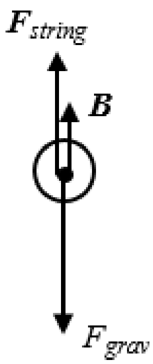
$$B = \rho_{fluid} V_{fluid} g = \rho_{fluid} V_{object} g = \rho_{fluid} \left(\frac{m_{object}}{\rho_{object}} \right) g$$

$$B = 1.00 \times 10^3 \text{ kg/m}^3 \left(\frac{0.255 \text{ kg}}{8.05 \times 10^3 \text{ kg/m}^3} \right) 9.80 \text{ m/s}^2 = \boxed{0.310 \text{ N}}$$

B4. Calculate the magnitude of the buoyant force on the wooden block.

The forces on the wooden block are its weight (downward), the buoyant force of the water (upward), and the tension in the string (downward).

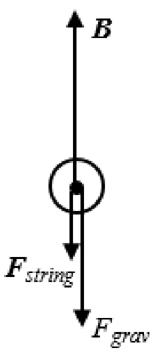
The forces on the steel object are its weight (downward), the buoyant force of the water (upward), and the tension in the string (upward):



The steel object is in equilibrium:

$$\sum F = 0$$
$$+F_{string} + B - F_{grav} = 0$$
$$F_{string} = F_{grav} - B = m_{steel}g - B = (0.255 \text{ kg})(9.80 \text{ m/s}^2) - 0.310 \text{ N} = 2.189 \text{ N}$$

Free-body diagram for the wooden block:



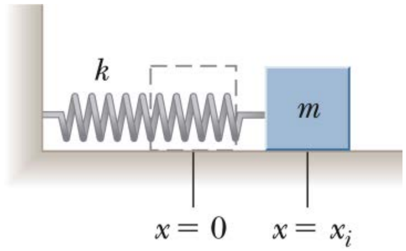
The wooden block is also in equilibrium:

$$\sum F = 0$$
$$+B - F_{string} - F_{grav} = 0$$
$$B = F_{string} + F_{grav} = F_{string} + m_{wood}g = 2.189 \text{ N} + (3.00 \text{ kg})(9.80 \text{ m/s}^2) = \boxed{31.6 \text{ N}}$$

B5. Which one of the following quantities is at a maximum when an object in simple harmonic motion is at its maximum displacement?

At maximum displacement the object is momentarily at rest, but it has maximum acceleration.

A block of mass m = 2.00 kg on a horizontal frictionless surface is attached to a horizontal spring of force constant k = 511 N/m, as shown in the diagram. The block is pulled to the right of equilibrium a distance of x_i = 5.00 cm and released from rest.



B6. Calculate the speed of the mass when it passes through the equilibrium position.

At the equilibrium position, all the energy of the system is kinetic energy of the moving mass. Initially, at maximum displacement, all the energy of the system is elastic potential energy. Since energy is conserved,

$$E = KE_{equilibrium} = PE_{max\,displacement}$$

$$\tfrac{1}{2}mv^2_{equilibrium} = \tfrac{1}{2}kx^2_{max}$$

$$v_{equilibrium} = x_{max}\sqrt{\frac{k}{m}} = (0.0500\text{ m})\sqrt{\frac{511\text{ N/m}}{2.00\text{ kg}}} = \boxed{0.799\text{ m/s}}$$

B7. Calculate the frequency of the oscillatory motion of the mass.

$$\omega = 2\pi f = \sqrt{\frac{k}{m}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{511\text{ N/m}}{2.00\text{ kg}}} = \boxed{2.54\text{ Hz}}$$

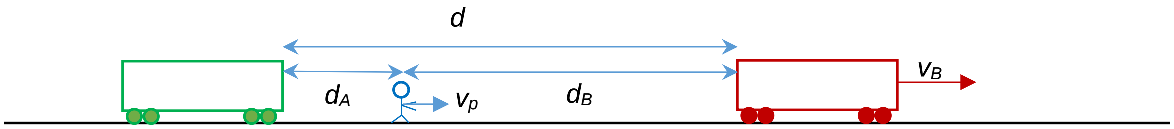
B8. Calculate the position of the mass at a time of 0.250 s after release.

$$x = A\cos(2\pi ft) = (0.0500\text{ m})\cos(2\pi \times 2.54\text{ Hz} \times 0.250\text{ s}) = \boxed{-0.0331\text{ m}}$$

(Remember that $2\pi ft$ is an angle in radians.)

At time $t = 0$, two trains are separated by a distance of 255 m. Train A is stationary and train B is moving toward the right (away from train A) at a speed of 40.0 m/s. The horns on both trains are identical and are both producing sounds with a frequency of 375 Hz. A listener is between the two trains, 85.0 m away from train A at time $t = 0$, and moving toward the right with a speed of 8.00 m/s. Assume that the speed of sound in air is 343 m/s.

B9. The power produced by one horn is 80.0 W. Calculate the intensity, due just to the horn on train A, received by the listener at time $t = 0$.



$$I_A = \frac{P}{A} = \frac{P}{4\pi d_A^{\,2}} = \frac{80.0\text{ W}}{4\pi(85.0\text{ m})^2} = \boxed{8.81\times10^{-4}\text{ W/m}^2}$$

B10. Calculate the intensity level of the total sound (due to both horns) received by the listener at time $t = 0$.

$$I_{tot} = I_A + I_B = 8.81\times10^{-4}\text{ W/m}^2 + I_B$$

$$I_B = \frac{P}{A} = \frac{P}{4\pi d_B^{\,2}} = \frac{P}{4\pi(d-d_A)^2} = \frac{80.0\text{ W}}{4\pi(255-85.0\text{ m})^2} = 2.20\times10^{-4}\text{ W/m}^2$$

$$I_{tot} = 8.81\times10^{-4}\text{ W/m}^2 + 2.20\times10^{-4}\text{ W/m}^2 = 1.10\times10^{-3}\text{ W/m}^2$$

$$\beta_{tot} = 10\text{dB}\log\left(\frac{I_{tot}}{I_0}\right) = 10\text{dB}\log\left(\frac{1.10\times10^{-3}\text{ W/m}^2}{1.00\times10^{-12}\text{ W/m}^2}\right) = \boxed{90.4\text{ dB}}$$

B11. Calculate the frequency of the sound of train A's horn, as heard by the listener.

The listener is an observer moving away from a stationary source. The listener speed is negative.

$$f_o = \left(\frac{v+v_o}{v-v_s}\right)f_s = \left(\frac{343\text{ m/s}+(-8.00\text{ m/s})}{343\text{ m/s}-0}\right)(375\text{ Hz}) = \boxed{366\text{ Hz}}$$

B12. Calculate the frequency of the sound of train B's horn, as heard by the listener.

The listener is moving toward the source (so listener speed is positive), but the source is moving away from the listener (negative source speed).

$$f_o = \left(\frac{v + v_o}{v - v_s}\right) f_s = \left(\frac{343\text{ m/s} + (+8.00\text{ m/s})}{343\text{ m/s} - (-40.0\text{ m/s})}\right)(375\text{ Hz}) = \boxed{344\text{ Hz}}$$

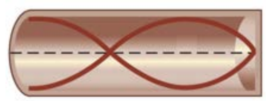
A pipe of length L is open at one end and closed at the other. The pipe is made to go into resonance at a frequency of 4.50×10^2 Hz. Assume that the speed of sound in air is 343 m/s.

B13. One of the following frequencies is the fundamental frequency for this pipe. Which one is it?

The fundamental frequency is less than or equal to 450 Hz. Since the pipe is open at one end and closed at the other, it only resonates at the fundamental and the odd harmonics. Therefore, if 450 Hz is not the fundamental, then the possibilities are (450 Hz)/3 = 150 Hz, (450 Hz)/5 = 90 Hz, etc. Therefore, from the given possibilities, the fundamental frequency is 150 Hz.

B14. Which one of the following is the correct diagram for the standing wave pattern in the pipe when it is in resonance at 4.50×10^2 Hz?

Since the pipe is open at one end and closed at the other, there is a node at the closed end and an antinode at the open end. Since the fundamental frequency is 150 Hz, 450 Hz corresponds to the third harmonic, and the second possible mode of resonance. The next simplest pattern that satisfies the boundary conditions is



B15. Calculate the length of the pipe.

When the pipe is resonating at 450 Hz there are 3 Node-Antinode segments along the pipe. Since each Node-Antinode segment corresponds to ¼ of the wavelength,

$$L = \tfrac{3}{4}\lambda = \tfrac{3}{4}\left(\frac{v}{f}\right) = \tfrac{3}{4}\left(\frac{343 \text{ m/s}}{450 \text{ Hz}}\right) = \boxed{0.572 \text{ m}}$$

B16. The closed end of the pipe is now opened and the pipe is made to go into resonance at 6.00×10^2 Hz. This frequency is…

When the closed end is opened, the pipe becomes one that is 0.572 m long and is open at both ends. The fundamental resonance mode is an antinode at each open end and one node in the middle of the pipe. Recall that the antinode-antinode distance is ½ of the wavelength…

$$L = \tfrac{1}{2}\lambda_1 \quad \Rightarrow \quad \lambda_1 = 2L \quad \Rightarrow \quad f_1 = \frac{v}{\lambda_1} = \frac{v}{2L} = \frac{343 \text{ m/s}}{2(0.572 \text{ m})} = 300 \text{ Hz}$$

Since the fundamental frequency is 300 Hz, 600 Hz corresponds to the second harmonic.

END OF EXAMINATION