Stu. No.: ____________________

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. Which one of the following statements concerning a mass connected to an ideal spring is ***NOT*** correct? $F = -kx$; $\omega = 2\pi f = \sqrt{\frac{k}{m}}$

E

(A) The restoring force of an ideal spring is proportional to the displacement from its unstrained length. ✓
(B) The restoring force always points in the direction opposite to the displacement from equilibrium. ✓
(C) The spring constant has units of N/m. ✓
(D) If no other forces act on the mass, then it will undergo simple harmonic motion when displaced from the equilibrium position. ✓
(E) The frequency of simple harmonic motion of the mass is independent of the spring constant.

A2. The statement, "any change in the pressure applied to a completely enclosed fluid is transmitted undiminished to all parts of the fluid and the enclosing walls", is known as

A

(A) Pascal's principle. (B) Archimedes' principle. (C) Torricelli's theorem.
(D) Bernoulli's principle. (E) Poiseuille's law.

A3. A wooden raft, with density ρ_{wood} and volume V_{wood} is floating completely submerged in water of density ρ_{water}. The magnitude of the buoyant force on the raft is given by:

A

(A) $F_B = \rho_{\text{water}} V_{\text{wood}} g$ (B) $F_B = (\rho_{\text{water}} - \rho_{\text{wood}}) V_{\text{wood}} g$ (C) $F_B = \dfrac{V_{\text{wood}} g}{\rho_{\text{water}}}$

(D) $F_B = \dfrac{V_{\text{wood}} g}{\rho_{\text{water}} - \rho_{\text{wood}}}$ (E) $F_B = \dfrac{\rho_{\text{water}} g}{V_{\text{wood}}}$

$F_B = W_{fluid} = \rho_{water} g V_{dis} = \rho_{water} g V_{wood}$

A4. Blood with viscosity η is flowing through a vein of radius R_1 and length L, with a volume flow rate of Q_1. The vein contracts, so that the new radius R_2 is only 90% of the original radius. If the pressure difference between the two ends of the vein remains the same, what is the new volume flow rate Q_2 in terms of Q_1? Poiseuille's Law: $Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta L} \Rightarrow Q \propto R^4$

E

(A) $Q_2 = 0.9\, Q_1$ (B) $Q_2 = 0.81\, Q_1$ (C) $Q_2 = \dfrac{Q_1}{0.81}$ (D) $Q_2 = 0.729\, Q_1$ (E) $Q_2 = 0.6561\, Q_1$

$Q_2 = (0.9)^4 Q_1$

A5. For a wave travelling along a guitar string, which one of the following statements is ***NOT*** correct?

C

$v = \sqrt{\frac{F}{m/L}}$

(A) The speed of the wave is dependent on the tension in the string. ✓
(B) The speed of the wave is dependent on the mass of the string. ✓
(C) The speed of the wave is dependent on the acceleration due to gravity.
(D) The speed of the wave is dependent on the length of the string. ✓
(E) The wave is a transverse wave. ✓

continued on page 3 ...

A6. Which one of the following changes will double the speed of a wave on a stretched string? $v_1 = \sqrt{\frac{F_1}{m/L_1}}$

(A) Double the tension in the string.

D

(B) Replace the string with one of half the linear density (and maintain the original tension).
(C) Halve the tension in the string.
(D) Replace the string with one of half the linear density, and double the tension. $v_2 = \sqrt{\frac{2F_1}{\frac{1}{2}(m/L)}} = 2\sqrt{\frac{F_1}{m/L_1}}$
(E) Replace the string with one of double the linear density (and maintain the original tension).

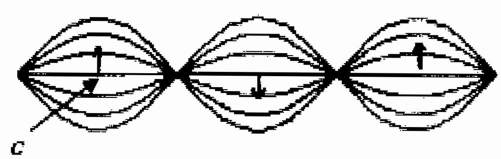
$= 2v_1$

A7. You are standing at the side of a highway as an emergency vehicle approaches at constant speed with its siren producing sound. Which one of the following statements is correct concerning the intensity and frequency of the sound that you hear as the vehicle approaches you? $f_o = f_s\left(\frac{1}{1-\frac{v_s}{v}}\right)$

B

(A) Both the intensity and frequency increase.
(B) The intensity increases and the frequency remains constant at a value higher than the frequency of sound produced by the siren.
(C) The intensity increases and the frequency remains constant at a value lower than the frequency of sound produced by the siren. $I = \frac{P}{A} = \frac{P}{4\pi r^2}$
(D) The frequency increases and the intensity remains constant.
(E) The intensity increases and the frequency decreases.

A8. A string fixed at both ends is plucked so that it vibrates in a standing wave pattern as shown. Let upward motion correspond to positive velocities. When the string is in position *c*, all points at 0 displacement from equilibrium, which one of the following statements is true?



E

(A) The instantaneous velocity is zero at all points along the string.
(B) The instantaneous velocity is positive at all points along the string.
(C) The instantaneous velocity is negative at all points along the string.
(D) The instantaneous velocity at the centre of the string is zero.
(E) The instantaneous velocity of points along the string depends on the position along the string.

$F_1 = k\frac{Qq}{r_1^2}$

A9. A charge Q exerts an electrostatic force of magnitude F on another charge q. If the distance between the charges is doubled, what is the magnitude of the force exerted on Q by q? $F_2 = \frac{kQq}{(2r_1)^2}$

A

(A) F/4 (B) 2 F (C) 4 F (D) $F/2$ (E) 3 F

A10. An insulated, negatively-charged rod approaches but does not touch a metal sphere, which is resting atop an insulated rod. Which one of the following statements is ***NOT*** correct? $F_2 = \frac{1}{4}\frac{kQ}{r_1^2}$

A

(A) The sphere is a good insulator.
(B) The sphere has many 'free' valence electrons, which are able to move on the sphere. ✓ $F_2 = \frac{1}{4}F_1$
(C) The rod induces a positive charge on the side of the sphere near the rod. ✓
(D) The rod induces a negative charge on the side of the sphere opposite the rod. ✓
(E) If the rod were to touch the sphere, the sphere would become negatively charged. ✓

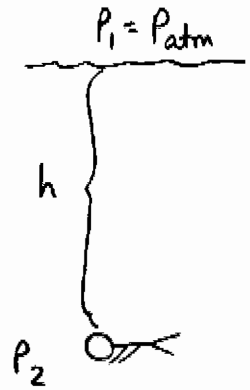
continued on page 4 ...

PART B

FOR EACH OF THE FOLLOWING PROBLEMS, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE 6.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. A deep sea diver starts at the surface of the ocean and dives to a depth of 30.5 m. The pressure at this depth is 4.06×10^5 Pa. Given that the density of sea water is 1.02×10^3 kg/m^3, calculate atmospheric pressure at the surface of the ocean.



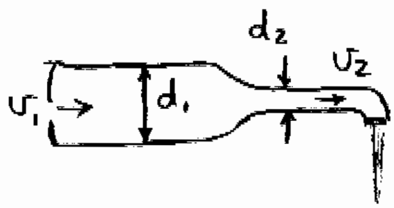
$$P_2 = P_1 + \rho g h$$

$$P_1 = P_{atm} = P_2 - \rho g h$$

$$P_{atm} = 4.06\times10^5 \text{Pa} - \left(1.02\times10^3 \frac{\text{kg}}{\text{m}^3}\right)\left(9.80 \text{m/s}^2\right)\left(30.5 \text{m}\right)$$

$$P_{atm} = 1.01\times10^5 \text{Pa}$$

B2. Water enters a building through a pipe 5.08 cm in diameter. The pipe tapers down to a 1.27-cm-diameter faucet from which water flows at a speed of 9.62 m/s. Assuming no branch pipes and ignoring viscosity, calculate the flow speed in the 5.08-cm-diameter main water pipe.



$$Q = Av = \text{constant (continuity)}$$

$$A_1 v_1 = A_2 v_2$$

$$v_1 = \frac{A_2 v_2}{A_1} = \frac{\pi\left(\frac{d_2}{2}\right)^2 v_2}{\pi\left(\frac{d_1}{2}\right)^2}$$

$$v_1 = \frac{d_2^2 v_2}{d_1^2} = \frac{(1.27\text{cm})^2(9.62\text{m/s})}{(5.08\text{cm})^2} = 0.601 \text{m/s}$$

continued on page 5 ...

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B3. A travelling wave of amplitude 1.25 cm is moving along a string in the negative x direction. If the wavelength is 10.0 cm, calculate the displacement of the string at time $t = 0$ for a position along the string of $x = -23.9$ cm.

wave moving to left: $y = A \sin\left(2\pi f t + \frac{2\pi x}{\lambda}\right)$

Since $t=0$, $y = A \sin\underbrace{\left(\frac{2\pi x}{\lambda}\right)}$ angle in radians

$$y = 1.25\,\text{cm} \sin\left(\frac{2\pi(-23.9\,\text{cm})}{10.0\,\text{cm}}\right)$$

$$y = -0.797\,\text{cm}$$

B4. Speaker A is producing a sound wave with a period of 0.0231 s and speaker B is producing a sound wave with a period of 0.0272 s. Calculate the frequency of the beats that are heard when both speakers are producing sound waves.

A 

B 

$$f_{beat} = |f_A - f_B|$$

$$f_{beat} = \left|\frac{1}{T_A} - \frac{1}{T_B}\right|$$

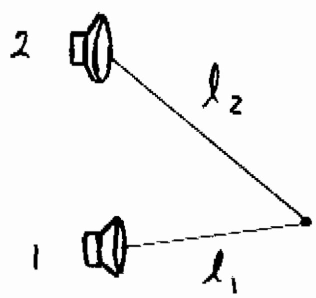
$$f_{beat} = \left|\frac{1}{0.0231\,\text{s}} - \frac{1}{0.0272\,\text{s}}\right|$$

$$f_{beat} = 6.53\,\text{Hz}$$

continued on page 6 ...

Stu. No.: ____________________

B5. A student stands 1.21 m from the left speaker of his stereo system and 2.55 m from the right speaker. A signal generator drives the speakers in phase, producing waves with the same amplitude and frequency. If the student hears no sound at this position, calculate the largest possible value for the wavelength of the sound.



no sound = destructive interference

$$\Rightarrow |\ell_1 - \ell_2| = (n + \tfrac{1}{2})\lambda$$

longest wavelength corresponds to smallest value for n ($=0$).

$$\therefore |\ell_1 - \ell_2| = \tfrac{1}{2}\lambda$$

$$\lambda = 2|\ell_1 - \ell_2| = 2|1.21\text{m} - 2.55\text{m}| = 2.68\text{m}$$

ANSWERS FOR PART B

ENTER THE ANSWERS FOR THE PART B PROBLEMS IN THE BOXES BELOW.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1	1.01×10^5 Pa
B2	0.601 m/s
B3	− 0.797 cm
B4	6.53 Hz
B5	2.68 m

continued on page 7 ...

PART C

IN EACH OF THE FOLLOWING QUESTIONS, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

SHOW YOUR WORK. NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY. EQUATIONS NOT PROVIDED ON THE FORMULA SHEET MUST BE DERIVED.

C1. The diaphragm of a loudspeaker is moving with simple harmonic motion, with a frequency of 215 Hz.

(a) Calculate the angular frequency, ω, of the oscillation.

$$\omega = 2\pi f = 2\pi\,(215\,\text{Hz}) = 1.35\times10^{3}\,\text{rad/s}$$

$\boxed{1.35\times10^{3}\,\text{rad/s}}$

(b) Given that the displacement of the diaphragm is 0.0541 m at time t = 2.50 s, calculate the amplitude of the speaker's motion.

$$x = A\cos(\omega t)$$

$\boxed{0.0904\,\text{m}}$

$$A = \frac{x}{\cos(\omega t)} = \frac{0.0541\,\text{m}}{\cos\left[\left(1.35\times10^{3}\,\text{rad/s}\right)\left(2.50\,\text{s}\right)\right]} = 0.0904\,\text{m}$$

(c) Given that the diaphragm has a mass of 0.0234 kg, calculate its kinetic energy at time t = 2.50 s.

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left(-A\omega\sin(\omega t)\right)^2$$

$\boxed{112\,\text{J}}$

$$KE = \frac{1}{2}(0.0234\,\text{kg})\left[-(0.0904\,\text{m})(1.35\times10^{3}\,\text{rad/s})\sin\left[\left(1.35\times10^{3}\,\tfrac{\text{rad}}{\text{s}}\right)(2.50\,\text{s})\right]\right]^2$$

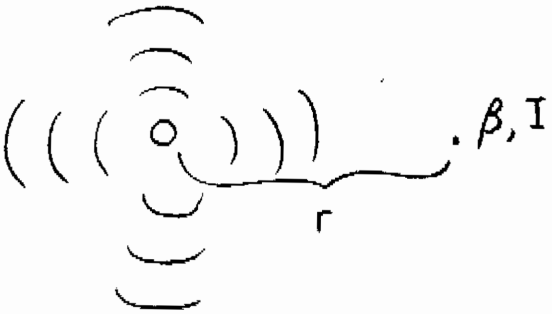
$$KE = 112\,\text{J}$$

continued on page 8 ...

C2. A speaker is producing sound energy at a constant rate of 6.51 W. The sound radiates uniformly in all directions. At a distance *r* from the speaker, the sound intensity level is 106 dB.

(a) Calculate the sound intensity at a distance *r* from the speaker.

$$\boxed{3.98 \times 10^{-2}\ \mathrm{W/m^2}}$$



$$\beta = 106\ \mathrm{dB} = 10 \log\left(\frac{I}{I_0}\right)$$

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

$$\frac{I}{I_0} = 10^{\beta/10} \Rightarrow I = I_0 \cdot 10^{\beta/10}$$

$$I = \left(1.00 \times 10^{-12}\ \frac{\mathrm{W}}{\mathrm{m}^2}\right)\left(10^{106/10}\right) = 3.98 \times 10^{-2}\ \mathrm{W/m^2}$$

(b) Calculate *r*.

$$\boxed{3.61\ \mathrm{m}}$$

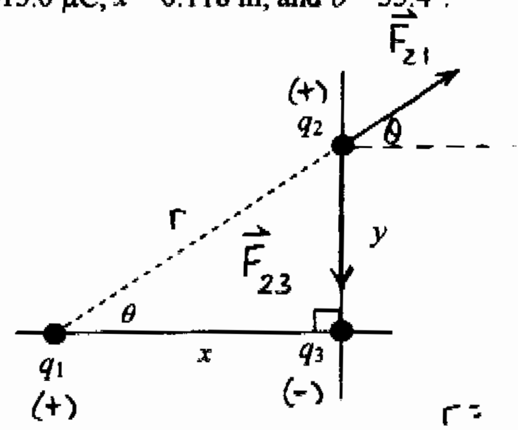
$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

$$r^2 = \frac{P}{4\pi I} \Rightarrow r = \sqrt{\frac{P}{4\pi I}} = \left(\frac{6.51\ \mathrm{W}}{4\pi\left(3.98 \times 10^{-2}\ \mathrm{W/m^2}\right)}\right)^{1/2}$$

$$r = 3.61\ \mathrm{m}$$

continued on page 9 ...

C3. Three charges are positioned as indicated in the figure: $q_1 = +11.0\ \mu C$, $q_2 = +15.0\ \mu C$, $q_3 = -13.0\ \mu C$, $x = 0.118$ m, and $\theta = 35.4°$.



$\tan\theta = \frac{y}{x}$

$y = x\tan\theta = 0.118\text{m}\tan(35.4°)$

$y = 0.0839\text{m}$

$\cos\theta = \frac{x}{r} \Rightarrow r = \frac{x}{\cos\theta}$

$r = \frac{0.118\text{m}}{\cos(35.4°)} = 0.145\text{m}$

Calculate the magnitude of the net electrostatic force on q_2 due to the other two charges.

$\boxed{216\text{ N}}$

$$F_{21} = k\frac{|q_1 q_2|}{r^2} = \frac{9.00\times10^9 \frac{\text{N.m}^2}{\text{C}^2}\left|(11.0\times10^{-6}\text{C})(15.0\times10^{-6}\text{C})\right|}{(0.145\text{m})^2}$$

$F_{21} = 70.6\text{ N}$

Similarly, $F_{23} = 249\text{ N}$

$\vec{F}_2 = \vec{F}_{21} + \vec{F}_{23} \Rightarrow F_{2x} = F_{21x} + F_{23x}$ and $F_{2y} = F_{21y} + F_{23y}$

$F_{2x} = F_{21}\cos\theta + 0 = 70.6\text{N}\cos(35.4°) = 57.6\text{N}$

$F_{2y} = F_{21}\sin\theta - F_{23} = 70.6\text{N}\sin(35.4°) - 249\text{N}$

$F_{2y} = -208\text{N}$

$\therefore F_2 = (F_{2x}^2 + F_{2y}^2)^{1/2} = 216\text{N}$

END OF EXAMINATION