Stu. No.: ____________________

PART A

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

A1. A spinning star begins to collapse under its own gravitational attraction. Which one of the following occurs as the star becomes smaller?

$\Sigma \tau_{ext} = 0$

(A) Its angular velocity decreases.
(B) Its angular momentum increases.
(C) Its angular velocity remains constant.
(D) Its angular momentum remains constant.
(E) Both its angular momentum and its angular velocity remain constant.

D

Ang. momentum is conserved

A2. Consider an object undergoing simple harmonic motion. The maximum distance that the object moves away from its equilibrium position is called the

E

(A) frequency. (B) period. (C) wavelength. (D) maximum cycle. (E) amplitude.

A3. Consider two horizontal pipes of the same length carrying the same viscous fluid. Both pipes have circular cross-sections, but the radius of pipe 1 is twice that of pipe 2. If the volume flow rates are the same for both pipes, the pressure differential applied across the length of pipe 2 is

E

(A) ½ the pressure differential applied across the length of pipe 1.
(B) twice the pressure differential applied across the length of pipe 1.
(C) four times the pressure differential applied across the length of pipe 1.
(D) eight times the pressure differential applied across the length of pipe 1.
(E) sixteen times the pressure differential applied across the length of pipe 1.

Poisseuille's Law

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8 \eta L}$$

$$R_1^4 \Delta P_1 = R_2^4 \Delta P_2$$

$$\Delta P_2 = \frac{R_1^4 \Delta P_1}{R_2^4}$$

$$\Delta P_2 = 16 \Delta P_1$$

A4. Consider wave pulses travelling along a taut rope. If the tension in the rope is increased by a factor of 9, how does the speed of the pulses change?

D

(A) The speed remains the same.
(B) The speed is reduced by a factor of 3.
(C) The speed is reduced by a factor of 9.
(D) The speed is increased by a factor of 3.
(E) The speed is increased by a factor of 9.

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

$$v \propto \sqrt{F}$$

A5. Two speakers are vibrating in-phase and producing sound waves of identical amplitude, A, frequency, f, and wavelength, λ. A listener is standing a distance ℓ_1 from speaker 1 and a distance ℓ_2 from speaker 2. If the listener is at a position of destructive interference, which one of the following statements could possibly be correct?

E

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

(A) $|\ell_1 - \ell_2| = 0$ (B) $|\ell_1 - \ell_2| = \lambda$ (C) $|\ell_1 - \ell_2| = 2\lambda$
(D) $|\ell_1 - \ell_2| = \frac{1}{4}\lambda$ (E) $|\ell_1 - \ell_2| = \frac{1}{2}\lambda$

continued on page 3 ...

A6. Which one of the following superpositions will result in beats?

E

(A) the superposition of waves that travel with different speeds.
(B) the superposition of identical waves that travel in the same direction.
(C) the superposition of identical waves that travel in opposite directions.
(D) the superposition of waves that are identical except for slightly different amplitudes.
(E) the superposition of waves that are identical except for slightly different frequencies.

A7. Which one of the following statements is true concerning the points on a string that sustain a standing wave pattern?

D

(A) All points vibrate with the same energy.
(B) All points undergo the same displacements.
(C) All points vibrate with different frequencies.
(D) Not all points vibrate with the same amplitude.
(E) All points undergo motion that is purely longitudinal.

$F = \frac{k|q_1 q_2|}{r^2} \Rightarrow F \propto \frac{1}{r^2}$

A8. Two positive point charges Q and $2Q$ are separated by a distance R. If the charge Q experiences a force of magnitude F when the separation is R, what is the magnitude of the force on the charge $2Q$ when the separation is increased to $2R$?

A

(A) ¼ F (B) ½ F (C) F (D) $2F$ (E) $4F$

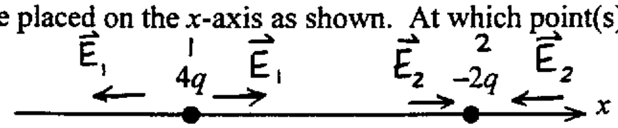
A9. Which one of the following statements is true concerning the electric field due to a point charge?

D

(A) The electric field depends on the mass of the point charge.
(B) The electric field vector due to a positive charge always points in the positive x-direction.
(C) The magnitude of the electric field due to a point charge depends on the sign of another point charge nearby.
(D) The magnitude of the electric field at a location twice as far from the point charge is four times weaker.
(E) The lines of the electric field due to a point charge are always parallel.

$E = \frac{k|q|}{r^2}$

A10. Two point charges are placed on the x-axis as shown. At which point(s) is the electric field equal to zero?



C

(A) The electric field is never zero in the vicinity of these charges.
(B) The electric field is zero somewhere on the x-axis to the left of the $4q$ charge.
(C) The electric field is zero somewhere on the x-axis to the right of the $-2q$ charge.
(D) The electric field is zero somewhere on the x-axis between the two charges, but closer to the $-2q$ charge.
(E) The electric field is zero at two points on the x-axis: one to the left of the $4q$ charge and one to the right of the $-2q$ charge.

continued on page 4 ...

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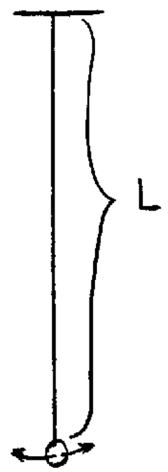
PART B

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 rope is hung from the top of a tower to the bottom of the tower, where a small object is attached forming a pendulum. The period of this pendulum is 9.25 s. Calculate the height of the tower.



$T = 9.25\,s$

$$\omega = \sqrt{\frac{g}{L}} = \frac{2\pi}{T}$$

$$\frac{g}{L} = \frac{4\pi^2}{T^2}$$

$$L = \frac{gT^2}{4\pi^2} = \frac{(9.80\,m/s^2)(9.25\,s)^2}{4\pi^2}$$

$$L = 21.2\,m$$

B2. A car travelling at 35.0 m/s approaches a stationary whistle that emits a 220 Hz sound. The speed of sound is 343 m/s. Calculate the frequency of the whistle's sound as heard by the driver of the car.

$v_o = 35.0\,m/s$

$v_s = 0$

$v = 343\,m/s$

$f_s = 220\,Hz$

toward

$$f_o = f_s\left(1 + \frac{v_o}{v}\right) = 220\,Hz\left(1 + \frac{35.0\,m/s}{343\,m/s}\right)$$

$$f_o = 242\,Hz$$

continued on page 5 ...

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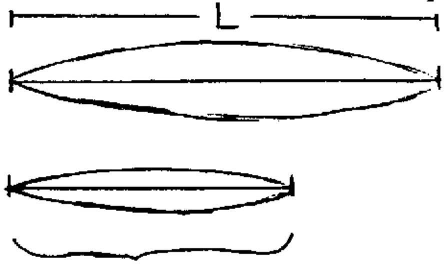
B3. Consider a violin string which has a fundamental frequency of 294 Hz when unfingered. Suppose it is held down (fingered) such that its effective length becomes two-thirds of its unfingered length. Calculate the new fundamental frequency. (The tension in the string is unaffected by fingering.)



$L' = \frac{2}{3}L$

At fundamental

$L' = \frac{\lambda'}{2}$

$\lambda' = 2L'$

At fundamental:

$L = \frac{\lambda}{2} \Rightarrow \lambda = 2L$

$v = f\lambda$

since v doesn't change

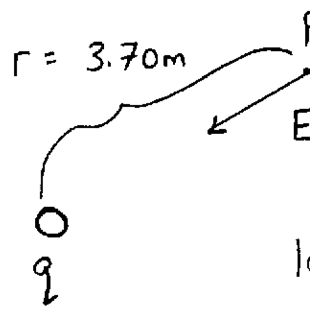
$f\lambda = f'\lambda'$

$f(2L) = f'(\cancel{2}L')$

$f' = \frac{fL}{L'} = \frac{294\text{Hz}\ L}{2/3\ L}$

$f' = 441\text{ Hz}$

B4. The magnitude of the electric field due to a small conducting sphere is 2.45×10^3 N/C at a distance of 3.70 m from the sphere. The conducting sphere is small enough so that at that distance it may be regarded as a point charge. Calculate the number of excess electrons residing on the conducting sphere.



$E = 2.45 \times 10^3\text{ N/C} = \frac{k|q|}{r^2}$

$|q| = \frac{Er^2}{k} = \frac{(2.45 \times 10^3\text{ N/C})(3.70\text{m})^2}{9.00 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2}$

$|q| = 3.73 \times 10^{-6}\text{ C}$

$q = ne \Rightarrow n = \frac{q}{e} = \frac{3.73 \times 10^{-6}\text{C}}{1.60 \times 10^{-19}\text{C}} = 2.33 \times 10^{13}$

continued on page 6 ...

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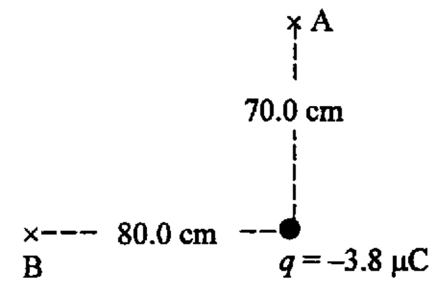
B5. Consider the situation shown in the diagram. Let V_A and V_B represent the absolute electric potentials at points A and B. Calculate the potential difference $V_{BA} = V_B - V_A$.



$$V = \frac{kq}{r}$$

$$V_B - V_A = kq\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

$$V_B - V_A = \left(9.00 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(-3.8 \times 10^{-6}\,\text{C}\right)\left(\frac{1}{0.800\,\text{m}} - \frac{1}{0.700\,\text{m}}\right)$$

$$V_B - V_A = 6.11 \times 10^3\,\text{V}$$

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	21.2 m
B2	242 Hz
B3	441 Hz
B4	2.33×10^{13}
B5	6.11×10^3 V

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.

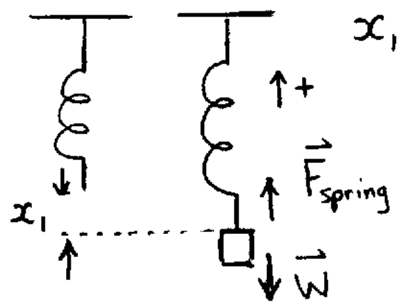
THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

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

C1. An object freely suspended from a vertical ideal spring of spring constant 250 N/m causes the spring to stretch 0.0560 m from its unstrained length.

(a) Calculate the mass of the object.

$\boxed{1.43\ \text{kg}}$

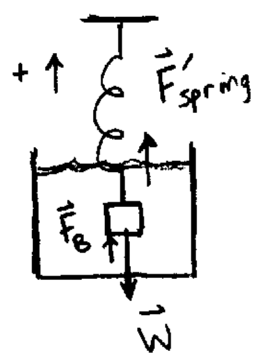


$x_1 = 0.0560\text{m}$

$$\sum \vec{F} = 0$$
$$F_{spring} - W = 0$$
$$kx - mg = 0$$
$$kx = mg$$
$$m = \frac{kx}{g}$$
$$m = \frac{(250\ \text{N/m})(0.0560\text{m})}{9.80\ \text{m/s}^2}$$
$$m = 1.43\ \text{kg}$$

(b) The object, still suspended from the spring, is now lowered into a container of water until the object is completely submerged but not touching the sides or bottom of the container. The spring is now 0.0475 m longer than its unstrained length. The density of water is 1000 kg/m³. Calculate the density of the object.

$\boxed{6.55\times10^3\ \text{kg/m}^3}$



$$\sum \vec{F} = 0$$
$$F'_{spring} + F_B - W = 0$$
$$kx' + \frac{\rho_{H_2O}\, g m}{\rho_{obj}} - mg = 0$$
$$kx' + \frac{\rho_{H_2O}\, g m}{\rho_{obj}} = mg$$

Buoyant Force, F_B:

$F_B = W_{fluid}$

$F_B = \rho_{H_2O}\, g V_{fluid}$

$F_B = \rho_{H_2O}\, g V_{obj}$

fully submerged.

and $V_{obj} = \dfrac{m}{\rho_{obj}}$

so $F_B = \rho_{H_2O}\, g\, m/\rho_{obj}$

$$\frac{\rho_{H_2O}\, g m}{\rho_{obj}} = mg - kx'$$
$$\rho_{H_2O}\, g m = \rho_{obj}(mg - kx')$$
$$\rho_{obj} = \frac{\rho_{H_2O}\, g m}{mg - kx'} = \frac{(1000\ \text{kg/m}^3)(9.80\text{m/s}^2)(1.43\text{kg})}{(1.43\text{kg})(9.80\ \text{m/s}^2) - (250\ \text{N/m})(0.0475\text{m})} \approx \rho_{obj} = 6.55\times10^3\ \text{kg/m}^3$$

—continued on page 8 ...

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C2. An incoming comet explodes in mid-air and generates a sound wave which radiates uniformly in all directions. At a distance of $r = 50.0$ km from the blast, the sound intensity level is measured to be $\beta = 183$ dB, relative to the threshold of hearing.

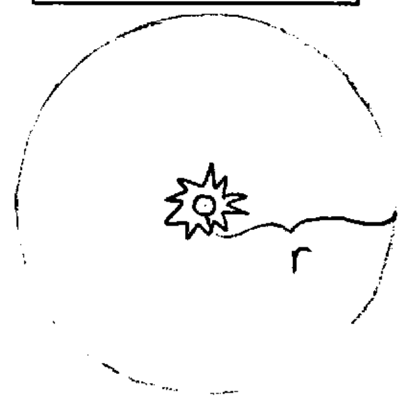
(a) Derive an expression which gives the power in the sound wave, P, in terms of r and β.

$$\beta = 10 \log\left(\frac{I}{I_0}\right); \quad I = \frac{P}{A}; \quad A = 4\pi r^2$$

$$\boxed{4\pi r^2 I_0 10^{\beta/10}}$$

$$\Downarrow \qquad \qquad \Downarrow$$

$$P = IA = I\,4\pi r^2$$



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

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

$$P = I(4\pi r^2) = 4\pi r^2 I_0\, 10^{\beta/10}$$

(b) Using your result from part (a), calculate the power in the sound wave generated by the explosion.

$$P = 4\pi (50.0\times 10^3\,\text{m})^2 (1.00\times 10^{-12}\,\text{W/m}^2)\, 10^{183/10}$$

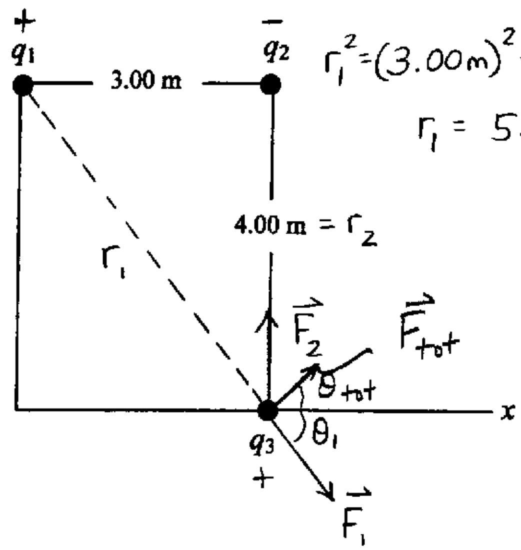
$$\boxed{6.27\times 10^{16}\,\text{W}}$$

$$P = 6.27\times 10^{16}\,\text{W}$$

continued on page 9 ...

C3. Consider the system of three charges arranged at the corners of a rectangle as shown in the diagram. Now suppose the charge q_3 is released from its position on the rectangle while the other two charges are fixed. Calculate the acceleration of charge q_3 (magnitude and direction relative to the +x axis) at the moment that it is released.

Charge 1: $q_1 = +5.25\ \mu C$ Charge 2: $q_2 = -3.33\ \mu C$ Charge 3: $q_3 = +7.00\ \mu C$, $m_3 = 0.785$ kg



$r_1^2 = (3.00\text{m})^2 + (4.00\text{m})^2$

$r_1 = 5.00\text{m}$

magnitude:	0.0106 m/s²
direction:	17.7° above +x

$$F_1 = \frac{k|q_1 q_3|}{r_1^2}$$

$$F_1 = \frac{\left(9.00\times10^9 \frac{N\cdot m^2}{C^2}\right)|(+5.25\times10^{-6}C)(+7.00\times10^{-6}C)|}{(5.00m)^2}$$

$$F_1 = 0.01323\ N$$

$$F_2 = \frac{k|q_2 q_3|}{r_2^2} = 0.01311\ N$$

$$\theta_1 = \text{invtan}\left(\frac{4.00m}{3.00m}\right) = 53.1°$$

$$\vec{a} = \frac{\vec{F}_{tot}}{m} = \frac{\vec{F}_1 + \vec{F}_2}{m}\ ;$$

$$F_{tot_x} = F_{1_x} = F_1\cos\theta_1 = 0.007938\ N$$

$$F_{tot_y} = -F_{1_y} + F_{2_y} = -F_1\sin\theta_1 + F_2 = 0.002526\ N$$

$$F_{tot} = \left(F_{tot_x}^2 + F_{tot_y}^2\right)^{1/2} = 0.00833\ N$$

$$\theta_{tot} = \text{invtan}\left(\frac{F_{tot_y}}{F_{tot_x}}\right) = 17.7°$$

$$a = \frac{F_{tot}}{m} = \frac{0.00833N}{0.785\ kg} = 0.0106\ m/s^2$$

END OF EXAMINATION