UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 111.6
<u>MIDTERM TEST #3</u>

January 29, 2004 Time: 90 minutes

NAME: ________________________________ STUDENT NO.: __________
(Last) **Please Print** (Given)

LECTURE SECTION (please circle):

01 Dr. A. Robinson
02 B. Zulkoskey
[illegible] Dr. [illegible] McWilliams
C15 F. D[illegible]n

<u>INSTRUCTIONS:</u>

1. You should have a test paper, a formula sheet, and an OMR sheet. The test paper consists of 9 pages. **It is the responsibility of the student to check that the test paper is complete.**
2. Enter your name and <u>STUDENT NUMBER</u> on the OMR sheet.
3. The test paper, the formula sheet and the OMR sheet must all be submitted.
4. The test paper will be returned. The formula sheet and the OMR sheet will <u>NOT</u> be returned.

PLEASE DO NOT WRITE ANYTHING ON THIS TABLE

QUESTION NO.	MAXIMUM MARKS	MARKS OBTAINED
Part A	10	
Part B	10	
C1	5	
C2	5	
C3	5	
TOTAL	35	

continued on page 2 ...

Stu. No.: ____________________

B5. A police car is in hot pursuit of a carload of bank robbers. The police car is travelling at a speed of 50.0 m/s with its siren blaring and the robber's car is travelling at a speed of 45.0 m/s. If the siren produces a sound wave with a frequency of 980 Hz, calculate the frequency of the siren sound wave that the robbers hear. The speed of sound in air is 343 m/s.

ALTERNATIVE EXAM

ANSWERS

ANSWERS FOR PART B

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

THE ANSWERS MUST BE EXPRESSED TO THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

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

B1	1.36×10^{3} kg/m^{3}
B2	0.161 J
B3	3.43×10^{3} Hz
B4	-2.57×10^{4} V
B5	997 Hz

PART A:

A1. B	A6. D
A2. C	A7. C
A3. D	A8. D
A4. D	A9. B
A5. A	A10. B

continued on page 7 ...

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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 an object undergoing simple harmonic motion is **FALSE**?

D

(A) The object has a maximum velocity when it is at the equilibrium position. T
(B) The object's acceleration has a maximum magnitude at the points of maximum displacement. T
(C) The object has a velocity of zero at the points of maximum displacement. T
(D) The object has a constant velocity. F $v = -A\omega \sin \omega t$
(E) The object has a displacement which has a sinusoidal variation with time. T

A2. A simple pendulum has a frequency of f_1 when on the earth. The same pendulum is taken to the moon, where it has a frequency f_2. What is the relationship between f_2 and f_1, given that the acceleration due to gravity on the moon is one-sixth that on the earth?

D

(A) $f_2 = 6f_1$ (B) $f_2 = (\sqrt{6})f_1$ (C) $f_2 = \frac{f_1}{6}$ (D) $f_2 = \frac{f_1}{\sqrt{6}}$ (E) $f_2 = 36f_1$

$\omega = \sqrt{\frac{g}{L}} \Rightarrow f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$; $f_2/f_1 = \frac{1}{2\pi}\sqrt{\frac{g_M}{L}} \Big/ \frac{1}{2\pi}\sqrt{\frac{g_E}{L}} = \sqrt{\frac{g_M}{g_E}} = \sqrt{\frac{1}{6}} \Rightarrow f_2 = \frac{f_1}{\sqrt{6}}$

A3. A raft of total mass M kg and area A m^2 is floating in water (density ρ kg/m^3). A distance h metres of the raft is below the water line. Which one of the following relationships is correct?

A

(A) $M = Ah\rho$ (B) $M = \frac{\rho A}{gh}$ (C) $M = \frac{\rho}{Ah}$ (D) $M = \frac{g}{Ah\rho}$ (E) $M = \frac{h\rho}{A}$

FLOATING $\Rightarrow F_B = Mg \Rightarrow \rho g V_{dis} = Mg \Rightarrow \rho g Ah = Mg \Rightarrow M = Ah\rho$

A4. An incompressible viscous fluid flows through a pipe of length L and radius R. The pressure difference between the ends of the pipe is P and the volume flow rate is Q. If the same fluid were to flow through a pipe of length L and radius ½R, and the pressure difference were doubled, the new volume flow rate would be

D

(A) Q (B) ½Q (C) $2Q$ (D) $Q/8$ (E) $Q/16$

$Q \propto R^4 \cdot \Delta P \Rightarrow Q_{new} = (\frac{1}{2})^4 \cdot 2 \cdot Q \Rightarrow Q_{new} = \frac{1}{8}Q$

A5. When a sound wave with a frequency of 256 Hz interferes with a sound wave with a frequency of 289 Hz, the resulting beat frequency is

B

(A) 1 Hz (B) 33 Hz (C) 11 Hz (D) 16.5 Hz (E) 5.5 Hz

$f_b = |f_2 - f_1|$

A6. Two speakers, separated by a distance d, are vibrating in phase and producing sound of identical frequency, f, and wavelength, λ. A listener wishes to position herself at a location of constructive interference. If her distance from one of the speakers is l, which one of the following choices for her distance from the **other** speaker will **ensure** that she is at a position of constructive interference?

C

(A) $l + d$ (B) $l - d$ (C) $l + \lambda$ (D) $l -$ ½λ (E) $d + \lambda$

Constructive interference:

$l_2 - l_1 = n\lambda \Rightarrow l_2 = l, l \pm \lambda, l \pm 2\lambda, \ldots$

continued on page 3 ...

A7. Two spherical conductors of equal size are held 1 m apart on an insulating table. The charge on sphere A is $+2Q$ and the charge on sphere B is $-4Q$. The spheres are now allowed to touch and are then put back to their original locations. Which one of the following statements is correct concerning the nature of the electrostatic force between the spheres prior to touching, and the spheres' charges after touching?

B

(A) initially attractive force; after touching: $q_A = 0$, $q_B = -2Q$
(B) initially attractive force; after touching: $q_A = -Q$, $q_B = -Q$
(C) initially attractive force; after touching: $q_A = +3Q$, $q_B = -3Q$
(D) initially repulsive force; after touching: $q_A = -Q$, $q_B = -Q$
(E) initially repulsive force; after touching: $q_A = -2Q$, $q_B = 0$

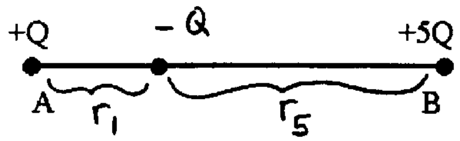
charge distributes equally when spheres are brought together.

$\therefore q_A, q_B = \dfrac{+2Q + (-4Q)}{2}$

$\therefore q_A, q_B = -Q$

A8. Two point charges +Q and +5Q are located at points A and B as shown. Consider a point charge –Q. Which of the following statements is true concerning where –Q can be placed so that it feels no net electrostatic force?

B



left of A ⇒ net force to right
right of B ⇒ net force to left
between A and B, oppositely-directed forces.

(A) –Q is at equilibrium to the left of A.
(B) –Q is at equilibrium between A and B, closer to A.
(C) –Q is at equilibrium to the right of B.
(D) –Q is at equilibrium between A and B, closer to B.
(E) –Q would not achieve equilibrium in this system.

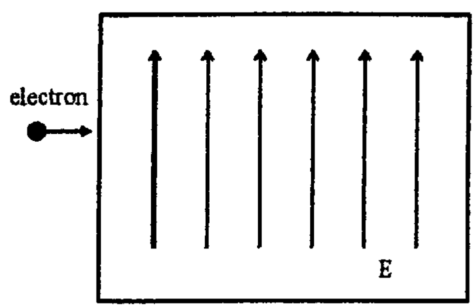
$|F_{+Q}| = |F_{+5Q}|$

$\dfrac{\cancel{k|-Q|}|+Q|}{r_1^2} = \dfrac{\cancel{k|-Q|}|+5Q|}{r_5^2}$

$\therefore r_5^2 = 5r_1^2$

A9. An electron traveling horizontally enters a region where a uniform electric field is directed upward, as shown in the diagram. What is the direction of the force exerted on the electron once it has entered the field?

D



(A) to the left
(B) to the right
(C) upward
(D) downward
(E) into the page, away from the reader

$\vec{F} = q\vec{E}$

$\vec{F} = -e\vec{E}$ opposite dir'n.

A10. A potential difference of 10 V is maintained between two parallel plates. If a proton is released from rest at the positive plate, its kinetic energy when it reaches the negative plate will be

B

(A) 1.6×10^{-18} eV. (B) 10 eV. (C) 10 J. (D) 10 W. (E) -1.6×10^{-19} C.

$E_A = E_B$

$EPE_A + KE_A = EPE_B + KE_B$

$EPE_A - EPE_B = KE_B$

$q_p(V_A - V_B) = KE_B$

$+e(10V) = KE_B$

$10eV = KE_B$

continued on page 4 ...

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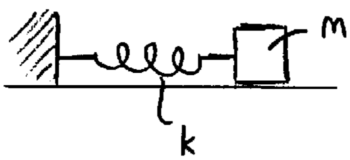
PART B

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 small mass of 0.300 kg is attached to a horizontal ideal spring and is vibrating horizontally across a frictionless table. The spring has a spring constant of 345 N/m. Calculate the total mechanical energy of the system when the mass is displaced 2.50 cm from the unstrained position of the spring and the speed of the mass is 0.550 m/s.



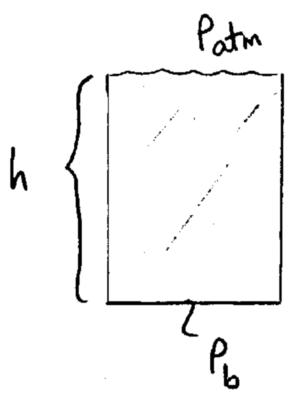
$$E = KE + PE_{elas}$$

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

$$E = \frac{1}{2}(0.300\,\text{kg})(0.550\,\text{m/s})^2 + \frac{1}{2}(345\,\text{N/m})(0.0250\,\text{m})^2$$

$$E = 0.153\,\text{J}$$

B2. An open container of height 55.0 cm is full to the top with maple syrup. The pressure at the bottom of the container is 1.07×10^5 Pa. Calculate the density of maple syrup, if atmospheric pressure is 1.01×10^5 Pa.



$$P_b = P_{atm} + \rho g h$$

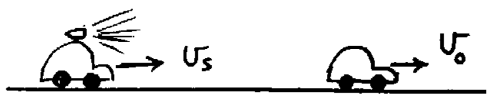
$$\frac{P_b - P_{atm}}{gh} = \rho$$

$$\rho = \frac{1.07 \times 10^5\,\text{Pa} - 1.01 \times 10^5\,\text{Pa}}{(9.80\,\text{m/s}^2)(0.550\,\text{m})}$$

$$\rho = 1.11 \times 10^3\,\text{kg/m}^3$$

continued on page 5 ...

B3. A police car is in hot pursuit of a carload of bank robbers. The police car is travelling at a speed of 50.0 m/s with its siren blaring and the robber's car is travelling at a speed of 45.0 m/s. If the siren produces a sound wave with a frequency of 980 Hz, calculate the frequency of the siren sound wave that the robbers hear. The speed of sound in air is 343 m/s.



source moving toward observer
observer moving away from source

$$f_o = f_s \left(\frac{1 - \frac{v_o}{v}}{1 - \frac{v_s}{v}} \right)$$

$$f_o = 980\text{ Hz} \left(\frac{1 - \frac{45.0\text{ m/s}}{343\text{ m/s}}}{1 - \frac{50.0\text{ m/s}}{343\text{ m/s}}} \right) = 997\text{ Hz}$$

B4. The human ear canal can be considered to be like an organ pipe that is closed at one end (at the eardrum) and open at the other. A typical ear canal has a length of 2.40 cm. Calculate the fundamental frequency of the ear canal. The speed of sound in air is 343 m/s.

$L = \frac{1}{4}\lambda_1$

$$f_1 = \frac{v}{\lambda_1} = \frac{v}{4L} = \frac{343\text{ m/s}}{4(0.0240\text{ m})} = 3.57 \times 10^3\text{ Hz}$$

continued on page 6 ...

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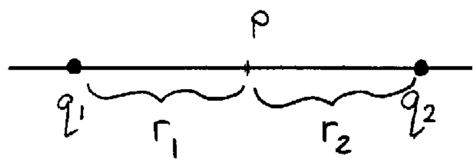
B5. A point charge of $+4.00 \times 10^{-6}$ C and a point charge of -6.00×10^{-6} C are held a distance of 1.25 m apart. Calculate the absolute electrostatic potential at the point midway between the two charges.



$$V_p = V_{p_1} + V_{p_2}$$

$$V_p = \frac{kq_1}{r_1} + \frac{kq_2}{r_2}$$

$$r_1 = r_2 = \frac{1.25\,m}{2} = r$$

$$V_p = \frac{k}{r}(q_1 + q_2)$$

$$V_p = \left(\frac{9.00 \times 10^9\, N \cdot m^2/C^2}{0.625\, m}\right)\left(+4.00 \times 10^{-6} C + (-6.00 \times 10^{-6} C)\right)$$

$$V_p = -2.88 \times 10^4 V$$

ANSWERS FOR PART B

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B1	0.153 J
B2	1.11×10^3 kg/m^3
B3	997 Hz
B4	3.57×10^3 Hz
B5	-2.88×10^4 V

continued on page 7 ...

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PART C

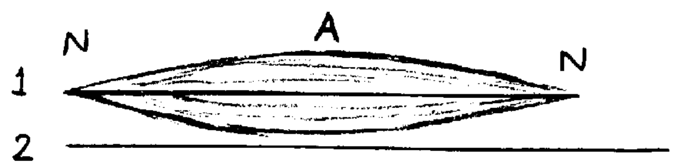
IN EACH OF THE FOLLOWING QUESTIONS, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST BE EXPRESSED TO 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. Two strings that are fixed at each end are identical, except that one is 0.0350 m longer than the other. The strings have a mass per unit length of 6.50×10^{-4} kg/m and a tension of 40.9 N, and the fundamental frequency of the shorter string is 212 Hz. Calculate the length of the longer string.

$\boxed{0.627 m}$



$L_2 = L_1 + 0.0380 m$

$F_2 = F_1 = 40.9 N$; $\frac{m_1}{L_1} = \frac{m_2}{L_2} = 6.50 \times 10^{-4} kg/m$

$f_{1_1} = 212 Hz$

At fundamental, $L = \frac{\lambda}{2}$

$v = \sqrt{\frac{F}{m/L}} \Rightarrow v_1 = v_2 = \sqrt{\frac{40.9 N}{6.50 \times 10^{-4} kg/m}} = 2.51 \times 10^2 m/s$

from $v = f\lambda$, $\lambda_{1_1} = \frac{v}{f_{1_1}} = \frac{2.51 \times 10^2 m/s}{212 Hz} = 1.184 m$

$\therefore L_1 = \frac{\lambda_{1_1}}{2} = 0.592 m$

$\therefore L_2 = L_1 + 0.0350 m = 0.627 m$

continued on page 8 ...

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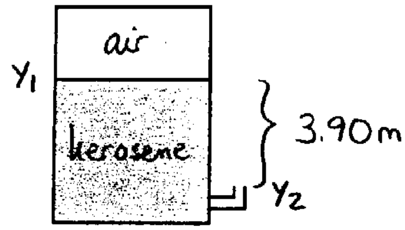
C2. In a very large closed storage tank for kerosene (density $\rho = 0.810 \times 10^3$ kg/m^3), the absolute pressure of the air above the kerosene is 5.99×10^5 Pa. The kerosene leaves the tank through a nozzle directed straight upwards. The opening of the nozzle is 3.90 m below the surface of the kerosene.



(a) Calculate the speed at which the kerosene leaves the nozzle, assuming atmospheric pressure is 1.01×10^5 Pa.

$\boxed{36.1\text{ m/s}}$

Bernoulli's Principle

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$P_1 - P_2 + \frac{1}{2}\rho v_1^2 + \rho g (y_1 - y_2) = \frac{1}{2}\rho v_2^2$$

$$\left[\frac{2(P_1 - P_2)}{\rho} + v_1^2 + 2g(y_1 - y_2)\right]^{1/2} = v_2$$

$$v_2 = \left[\frac{2(5.99\times 10^5\text{Pa} - 1.01\times 10^5\text{Pa})}{0.810\times 10^3\text{kg/m}^3} + 0 + 2(9.80\text{m/s}^2)(3.90\text{m})\right]^{1/2}$$

$$v_2 = 36.1\text{ m/s}$$

(b) Calculate the height to which the kerosene rises above the nozzle (ignoring air resistance and viscous effects).

$\boxed{66.6\text{ m}}$

Use Bernoulli's b/w top of tank and top of "plume".

$$v_1 = v_2 = 0$$

$$P_1 + \rho g y_1 = P_2 + \rho g y_2$$

$$\frac{P_1 - P_2}{\rho g} + y_1 = y_2$$

$$y_2 = \frac{(5.99\times 10^5\text{Pa} - 1.01\times 10^5\text{Pa})}{(0.810\times 10^3\text{kg/m}^3)(9.80\text{m/s}^2)} + 3.90\text{m}$$

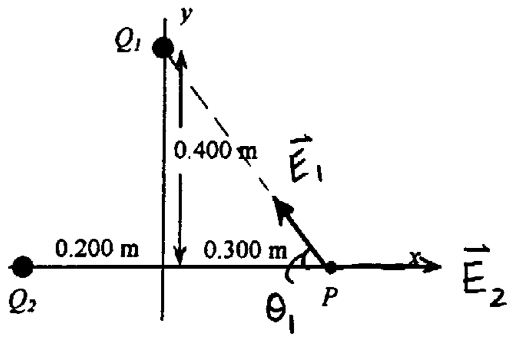
$$y_2 = 66.6\text{ m}$$

continued on page 9 ...

Stu. No.: ____________________

C3. Two point charges, $Q_1 = -1.25\ \mu C$ and $Q_2 = +8.66\ \mu C$, are held in place at (0, 0.400 m) and (–0.200 m, 0), respectively, as shown in the diagram.

(a) Calculate the electric field (magnitude and direction) at point *P*, located at (0.300 m, 0).



$r_1 = \sqrt{(0.300m)^2 + (0.400m)^2} = 0.500m$

$r_2 = 0.200m + 0.300m = 0.500m$

$E_1 = \dfrac{k|Q_1|}{r_1^2} = \dfrac{\left(9.00\times10^9 \frac{N\cdot m^2}{C^2}\right)(|-1.25\times10^{-6}C|)}{(0.500m)^2}$

$\theta_1 = \text{invtan}\left(\dfrac{0.400m}{0.300m}\right)$

$E_1 = 4.50\times10^4 N/C$

$\theta_1 = 53.1°$

Similarly, $E_2 = 3.12\times10^5 N/C$

Now, $\vec{E}_P = \vec{E}_1 + \vec{E}_2$

$\therefore E_{Px} = E_{1x} + E_{2x} = -E_1\cos\theta_1 + E_2$

$E_{Px} = -4.50\times10^4 N/C(\cos 53.1°) + 3.12\times10^5 N/C$

$E_{Px} = 2.85\times10^5 N/C$

$E_{Py} = E_{1y} + E_{2y} = E_1 \sin\theta_1 + 0$

$E_{Py} = (4.50\times10^4 N/C)\sin 53.1° = 3.60\times10^4 N/C$

$E_P = \sqrt{E_{Px}^2 + E_{Py}^2} = 2.87\times10^5 N/C$

$\theta_P = \text{invtan}\left(\dfrac{E_{Py}}{E_{Px}}\right) = 7.20°$ above $+x$

magnitude:	$2.87\times10^5 N/C$
direction: (relative to +*x* axis)	7.20° above (ccw)

END OF EXAMINATION