Circle instructor: Yethiraj or Morrow Name:________________________

Lab period: ____________ Student Number:______________________

MEMORIAL UNIVERSITY OF NEWFOUNDLAND
DEPARTMENT OF PHYSICS AND PHYSICAL OCEANOGRAPHY

Physics 1051 Winter 2010

Term Test 1 February 12, 2010

INSTRUCTIONS:

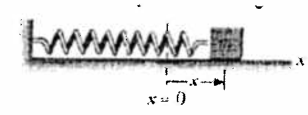
1. Do all questions. Marks are indicated in the left margin. Budget time accordingly.
2. Write your name and student number on each page.
3. You may use a calculator. All other aids are prohibited.
4. Write answers neatly in space provided. If necessary, continue onto the back of the page.
5. Do not erase or use "whiteout" to correct answers. Draw a line neatly through material to be replaced and continue with correction.
6. Assume all information given is accurate to 3 significant figures.
7. Don't panic. If something isn't clear, ASK!

SEE LAST PAGE FOR SOME POTENTIALLY USEFUL FORMULAE AND CONSTANTS

For office use only:

1	2	3	4	total

[10] 1. A 0.3-kg mass attached to a spring is oscillating on a horizontal frictionless surface with amplitude 2.7 cm. The maximum speed of the mass is 0.153 m/s.



(i) What is the total mechanical energy of the system?

(ii) What is the force constant of the spring?

(iii) At $t = 0$ s, the position of the mass is $x = 0$ cm and the velocity of the mass is positive. Assuming that the position of the mass is written as $x = A\cos(\omega t + \varphi)$, what is the phase constant φ?

(iv) What is the speed of the mass when $x = -2.0$ cm?

2 (i) $E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2 = \frac{1}{2}kA^2 = \frac{1}{2}mv_{max}^2$

$E = \frac{1}{2}(0.3\text{ kg})(0.153\text{ m/s})^2 = \frac{0.007}{2}\text{ J} = \frac{7\times10^{-3}}{2}\text{ J} = 3.5\times10^{-3}\text{ J}$

2 (ii) $k = \dfrac{\frac{1}{2}mv_{max}^2}{\frac{1}{2}A^2} = \dfrac{2E}{A^2} = \dfrac{7\times10^{-3}}{(0.027\text{ m})^2} = 9.63\text{ N/m}$

3 (iii) $x = A\cos(\omega t + \phi)$

$x_0 = A\cos\phi = 0 \Rightarrow \cos\phi = 0 \Rightarrow \phi = 0, \pi/2, -\pi/2, \pm 3\pi/2 \ldots$

$v = -A\omega\sin(\omega t + \phi)$

$v_0 = -A\omega\sin\phi$

If $\phi = \pi/2$, $\cos\phi = 0$, $\sin\phi = 1 \Rightarrow v_0 < 0$ X NO

If $\phi = -\pi/2$, $\cos\phi = 0$, $\sin\phi = -1 \Rightarrow v_0 > 0$ ✓ YES

If $\phi = 3\pi/2$, $\cos\phi = 0$, $\sin\phi = -1 \Rightarrow v_0 > 0$ ✓ YES

If $\phi = -3\pi/2$, $\cos\phi = 0$, $\sin\phi = +1 \Rightarrow v_0 < 0$ X NO

} Two possible answers + others at multiples of 2π.

3 (iv) Use $\phi = -\pi/2$ (but not important)

$x = A\cos(\omega t - \pi/2) = 2$ cm

$\cos(\omega t - \pi/2) = \frac{2}{2.7} \Rightarrow \sin(\omega t - \pi/2) = \sqrt{1 - \left(\frac{2}{2.7}\right)^2} = \sqrt{0.45} = 0.67$

$v = -A\omega\sin(\omega t - \pi/2) = -v_{max}\sin(\omega t - \pi/2)$

$= -(0.67)(0.153)$

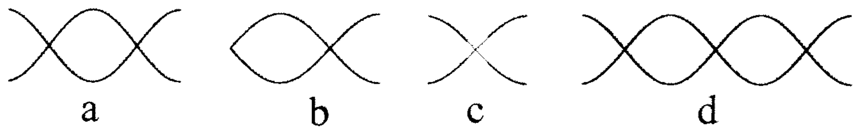
$= 0.1$ m/s

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

$\therefore v^2 = \left(\frac{2E - kx^2}{m}\right)$

$v = \sqrt{\dfrac{7\times10^{-3}\text{ J} - 9.63\times(.02)^2}{0.3\text{ kg}}} = 0.102$ m/s

[10] 2. (a) Two tubes, of different length, are both open at both ends. Tube A resonates at the **2nd harmonic** for the frequency of a particular tuning fork. Tube B resonates at the **3rd harmonic** for the **same** frequency.



(i) Which of the diagrams above best illustrates the pattern of displacement nodes and antinodes corresponding to **the 2nd harmonic** of a tube that is open at both ends?

(i) (a) 2

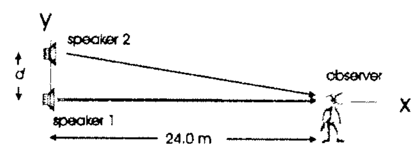
(ii) Tube B is 0.328 m longer than tube A. What is the wavelength of the sound generated by the tuning fork?

(iii) If the speed of sound is 343.2 m/s, what is the frequency of the tuning fork?

2 (ii) $L_B - L_A = \frac{\lambda}{2} \Rightarrow \lambda = 2(0.328) = 0.656$ m

2 (iii) $f = \frac{v}{\lambda} = \frac{343.2}{0.656} = 523.2$ Hz

(b) Two speakers, located along the y-axis as shown, sound waves in phase. Speaker 1 is at the origin. An observer is 24.0 m from speaker 1 along the x-axis as shown. Assume the speed of sound in air is 343.2 m/s.



(i) Assume that d is the smallest non-zero separation for which waves from the two speakers interfere constructively when the frequency emitted is 310.0 Hz. Find d.

(ii) If d remains fixed at the value found in part (i) while the frequency is halved, what is the resulting phase difference between the waves from arriving at the observer from the two speakers? (Hint: how does the wavelength change?)

(i)
2 First constructive int. after $\varphi = 0$ is $\varphi = 2\pi$.

$\phi = k(r_2 - r_1) = 2\pi \Rightarrow \frac{2\pi}{\lambda}(r_2 - r_1) = 2\pi$ so $\underline{r_2 - r_1 = \lambda}$

$r_2 = r_1 + \lambda = 24.0 \text{ m} + \frac{343.2}{310.0}$ ($v = f \cdot \lambda$) (so $\lambda = \frac{v}{f}$)

$= 25.11$ m

$r_2^2 = d^2 + 24^2 \Rightarrow d = \sqrt{r_2^2 - 24^2} = \sqrt{54.36} = 7.37$ m.

2

(ii) At half the frequency $\lambda = \frac{v}{(\frac{1}{2})(310)} = \frac{2 \cdot 343.2}{310} = 2.214$ m

$\phi = \left(\frac{2\pi}{\lambda}\right)(r_2 - r_1) = \left(\frac{2\pi}{2.214}\right)(1.107) = \pi$

[10] 3. (a) A sinusoidal wave propagates along a very long string in the positive x-direction. The linear density (mass per unit length) of the string is 0.0057 kg/m and the tension in the string is 9.5 N. The period of the wave is 0.041 s.

(i) What is the speed of propagation for this wave?

(ii) What is the wavelength of this wave?

(iii) If the amplitude of the wave is 0.032 m, what is the maximum transverse speed of a point on the string? (Hint: take the wave function to be $y = A\sin(kx - \omega t)$.)

2 (i) $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{9.5}{.0057}} = \sqrt{1666.67} = 40.82$ m/s

2 (ii) period $T_p = 0.041$ s $\quad f = 1/T_p = 24.39$ Hz

$\lambda = \frac{v}{f} = \frac{40.82}{24.39} = 1.67$ m.

3 (iii) $V_{y_{max}} = A\omega$. $\quad \omega = 2\pi f = 153.2$ rad/s

$= 0.032 \times 153.2 = 4.9$ m/s

(b) A string with a density of 0.0045 kg/m is stretched between two fixed points separated by 1.5 m. What is the tension if this string vibrates at 220 Hz in its fundamental mode?

3

fundamental $\frac{\lambda}{2} = L \quad \lambda = 2L = 3.0$ m.

$f = 220 \text{ Hz} = \frac{v}{\lambda} = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

$T = ((2L)f)^2 \mu$

$= 4.356 \times 10^5 \times 4.5 \times 10^{-3}$

$= 1960.2$ N

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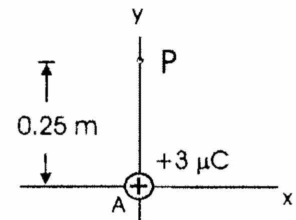
[10] 4. (a) One charge, $q_A = +3\,\mu C$, is located at the origin of an x-y system as shown. Point **P** is located on the y-axis at $y = 0.25\,\text{m}$.

(i) What is the electric field at point **P** due to charge A. Give your answer in unit vector notation?

(ii) A second charge, $q_B = -5\,\mu C$, is now placed on the x-y plane in a location such that the total electric field at point **P**, due to charges A and B, is 0. What are the coordinates of the location of charge B on the plane?



3 (i) $\vec{E}_{AP} = \frac{k_e q_A}{(0.25)^2}\hat{j}$

$= \frac{8.99\times10^9 \times 3\times10^{-6}}{(0.25)^2}\hat{j}\ \frac{N}{C}$

$= 431.5\times10^3\,\hat{j}\ N/C = 4.3\times10^5\,\hat{j}\ N/C$

3 (ii) $\vec{E}_{TOTAL} = \vec{E}_{AP} + \vec{E}_{BP} = 0 \Rightarrow \vec{E}_{BP} = -431.5\times10^3\,\hat{j}\ N/C$

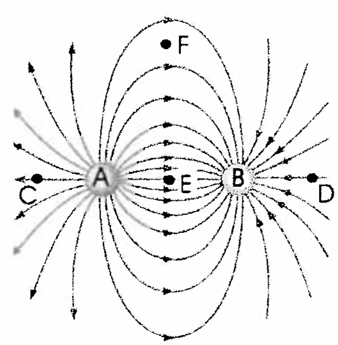
$\vec{E}_{BP} = \frac{k_e|q_B|}{r^2}(-\hat{j}) = -\frac{(8.99\times10^9)(5\times10^{-6})}{r^2}\hat{j} = -431.5\times10^3\,\hat{j}$ (N/C

$r^2 = \frac{44950}{431.5\times10^3} = 0.104 \Rightarrow |r| = 0.322\ m$

The position is therefore $(+0.25 - 0.322)\hat{j} = -0.073\hat{j}$ m

Coordinates $(0, -0.073\ m)$

(b) The figure to the right shows electric field lines around two charges, A and B.



1 (i) What is the sign of charge B?

negative

1 (ii) At which of the locations, labeled C, D, E, and F, is the magnitude of the electric field **largest**?

E

2 (iii) Of the locations labeled C, D, E, and F, identify any where a small **negative** charge would feel a force to the right.

C and D

Some Potentially Useful Formulae and Constants:

$$\frac{d^2x}{dt^2} = -\omega^2 x$$

$F_x = -k_{\text{spring}} x$ (Hooke's Law)

$$E = \frac{1}{2}k_{spring}x^2 + \frac{1}{2}mv^2$$

$\omega = \dfrac{2\pi}{T}$ (angular frequency)

$$\omega^2 = \frac{k_{spring}}{m}$$

$$\omega^2 = \frac{g}{L}$$

$$\omega^2 = \frac{mgd}{I}$$

$k = \dfrac{2\pi}{\lambda}$ (angular wave number)

$v = f\lambda$ (wave speed)

$$v = \sqrt{\frac{T}{\mu}}$$

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

$$\vec{F}_{12} = k_e \frac{q_1 q_2}{r^2}\hat{r}_{12}$$

$$\vec{E} = k_e \frac{q}{r^2}\hat{r}$$

$$\vec{E} = k_e \sum_i \frac{q_i}{r_i^2}\hat{r}_i$$

$$v_{\text{sound}} = 331\ \text{m/s} + 0.6\frac{\text{m}}{\text{s}\cdot{}^\circ\text{C}} \times T_{{}^\circ\text{C}}$$

$$\Phi_E = \int \vec{E}\cdot d\vec{A}$$

$$\Phi_E = \frac{q_{\text{inside}}}{\varepsilon_0}$$

$$V = k_e \frac{q}{r}$$

$$V = k_e \sum_i \frac{q_i}{r_i}$$

$$V_{\text{sphere}} = \frac{4}{3}\pi r^3$$

$$A_{\text{sphere}} = 4\pi r^2$$

Physical constants:

$$k_e = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$$

$$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$$

$$e = 1.60 \times 10^{-19}\ \text{C}$$

$$g = 9.81\ \text{m/s}^2$$