MEMORIAL UNIVERSITY OF NEWFOUNDLAND
DEPARTMENT OF PHYSICS AND PHYSICAL OCEANOGRAPHY

Final Exam **Physics 1051 Winter 2009** 3:00-5:00 April 22, 2009

INSTRUCTIONS:

1. Do all **SIX (6) questions** in section **1** and all **THREE (3)** questions in section **2**. Do **TWO** questions from section **3**. Marks are indicated in the left margin. Section 1 contains 36 marks, Section 2 contains 36 marks, and section 3 contains 28 marks. Budget time accordingly.

2. You may use a calculator. All other aids are prohibited.

3. Write answers neatly in space provided. If necessary, continue onto the back of the page.

4. Do not erase or use “whiteout”. Draw a line neatly through material to be replaced.

5. Assume all information given is accurate to 3 significant figures.

6. Don’t panic. If something isn’t clear, ASK!

SEE LAST PAGE FOR SOME POTENTIALLY USEFUL FORMULAE AND CONSTANTS

For office use only:

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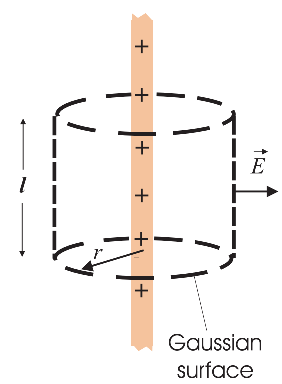
TOTAL	

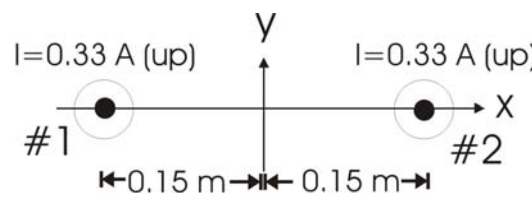
SECTION 1: There are 6 *SHORT ANSWER* questions. Each is worth 6 marks for a maximum of 36 marks. Budget time accordingly.

[6] 1. A wave is described by the function $y(x,t) = 0.017\text{ m} \cdot \sin\left[\left(8.4\text{ m}^{-1}\right)\cdot x - \left(75\text{ s}^{-1}\right)\cdot t\right]$.
(a) At what speed does this wave travel?
(b) What is the wavelength?

[6] 2. What is the magnitude of the electric field 10.0 cm away from a very long line of charge with a linear charge density of 6.3×10^{-9} C/m? You may find the drawing helpful.



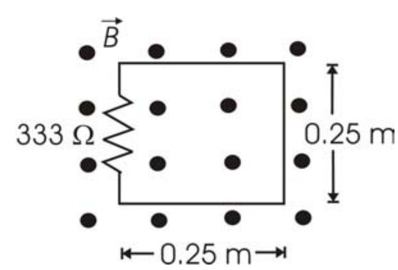
[6] 3. Wire #1 is located at $x = -0.15$ m and carries a current of 0.33 A out of the page (parallel to the z axis) as shown. Wire #2 is located at $x = +0.15$ m and also carries a current of 0.33 A out of the page (parallel to the z axis) as shown.



(a) What is the contribution to the magnetic field at the origin due to wire #1? Give your answer in unit vector notation.

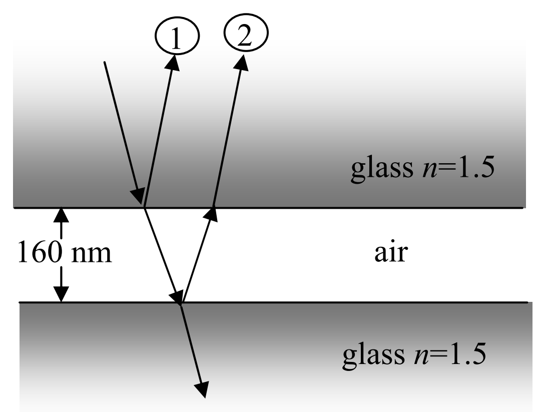
(b) What is the resultant magnetic field at the origin due to the effects of wire #1 and wire #2 together?

[6] 4. A square loop of wire, with sides of 0.25 m and a resistance of 333 Ω, is placed in a region where there is a magnetic field perpendicular to the plane of the loop and out of the page as shown. The magnetic field increases linearly with time and its magnitude is given by $B = 0.075t$ where t is in seconds and B is in Tesla. What is the magnitude and direction (clockwise or counterclockwise) of the resulting current?



[6] 5. Consider two identical guitar strings stretched to the same length. The tension in one string is 98 *N* and the fundamental frequency of the string is 440 Hz. The tension in the second string is 107 *N*. What beat frequency is heard when the two strings are both vibrating at their fundamental frequencies?

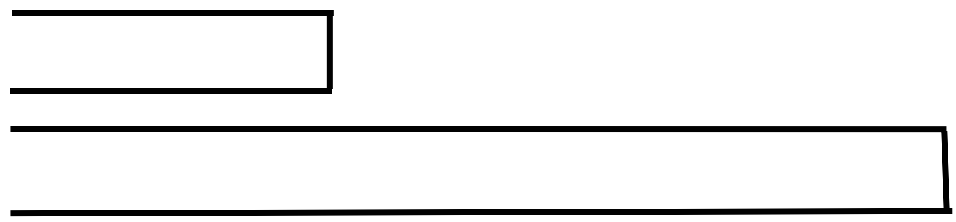
[6] 6. When light is incident on pair of flat, parallel glass slabs of glass (index of refraction $n = 1.5$) separated by a 160-nm air gap, constructive interference is observed. This is found to be the smallest gap for which constructive interference occurs. What is the wavelength of the light?



SECTION 2: Do ALL three (3) questions. Each question is worth 12 marks for a maximum of 36 marks.

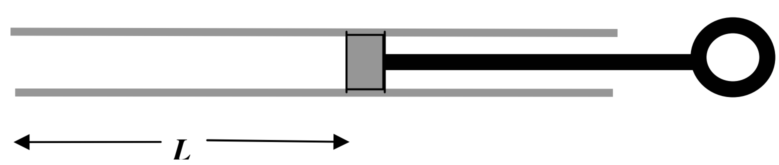
[12] 7. (a) In the diagrams below:

(i) sketch the standing wave modes corresponding to the fundamental frequency for a tube with one end open and the other closed and then (ii) sketch the next resonance encountered as the tube is lengthened (with wavelength held constant). Clearly indicate the displacement nodes and antinodes.



(b) In terms of wavelength λ, (i) how long is the tube that resonates at the fundamental frequency and (ii) how long is the tube that resonates at the next resonance?

(c) The diagram below shows a tube in which the distance, L, between an open end and a closed end can be varied. In an atmosphere containing an unknown gas at 0° C, two of the lengths at which sound waves (frequency $f = 1200\ \text{Hz}$) resonate in the tube are $L = 0.269\ \text{m}$ and $L = 0.376\ \text{m}$.



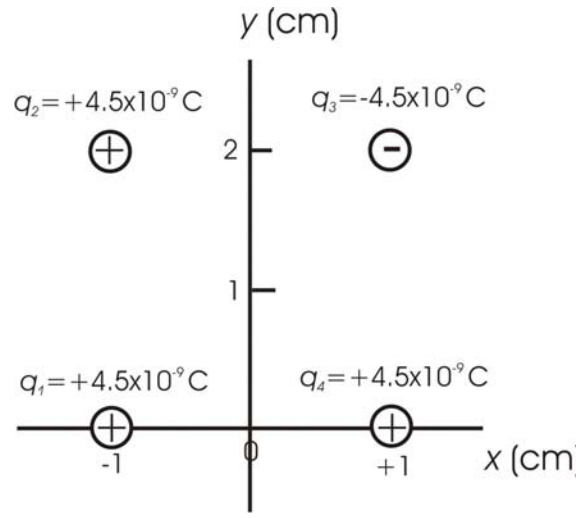
(i) What is the wavelength of the $f = 1200\ \text{Hz}$ sound wave in the unknown gas?

(ii) What is the speed of sound in the unknown gas?

(iii) The speeds of sound for CO_2, air, and H_2 at 0° C are reported to be 258 m/s, 331 m/s, and 1270 m/s respectively. Which of these gases is most similar to the unknown gas in this experiment?

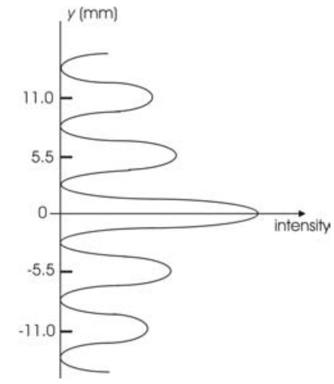
[12] 8. Four charges are positioned on the *x*-*y* plane as shown:

Charge $q_1 = +4.5\times10^{-9}$ C is at $x = -1$ cm, $y = 0$ cm.
Charge $q_2 = +4.5\times10^{-9}$ C is at $x = -1$ cm, $y = +2$ cm.
Charge $q_3 = -4.5\times10^{-9}$ C is at $x = +1$ cm, $y = +2$ cm.
Charge $q_4 = +4.5\times10^{-9}$ C is at $x = +1$ cm, $y = 0$ cm.



(a) What is the total electric potential at the origin?

(b) What is the total electric field at the origin? Give your answer in unit vector notation.



[12] 9. In a Young's double slit experiment, a pair of slits separated by 2.89×10^{-4} m is illuminated by plane light waves. The distance from the slits to the screen is 2.7 m. If the location of the central bright spot in the resulting interference pattern is designated as $y = 0$, then additional bright spots are seen at $y = \pm 5.5$ mm, $y = \pm 11.0$ mm, $y = \pm 16.5$ mm, etc. as shown.

(a) What is the wavelength, λ, of the incident light?

(b) What is the difference between the path lengths for the light reaching the spot at $y = +11.0$ mm from the more distant slit and the light reaching the spot at $y = +11.0$ mm from the closer slit?

(c) If the slit separation was made smaller, would the separation between the bright spots increase or decrease?

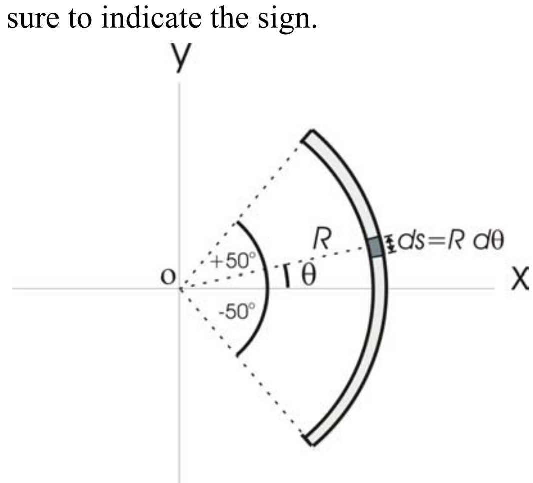
SECTION 3: Do TWO (2) of the three questions. Each question is worth 14 marks for a total of 28 marks. Indicate clearly the one question that you do not want marked by drawing a line through it (don't erase!).

[14] 10. A segment (arc) of a non-conducting charged ring, centred on the origin, subtends the angle from $\theta_1 = -50^\circ$ to $\theta_2 = +50^\circ$ as shown. The radius of the ring is 0.55 m and the linear charge density on the ring is $\lambda = 8.0 \times 10^{-12}$ C/m.

(a) Without doing an integral, what is the *y*-component, E_y, of the total electric field at the origin due to the entire charged ring segment (from $\theta_1 = -50^\circ$ to $\theta_2 = +50^\circ$)?

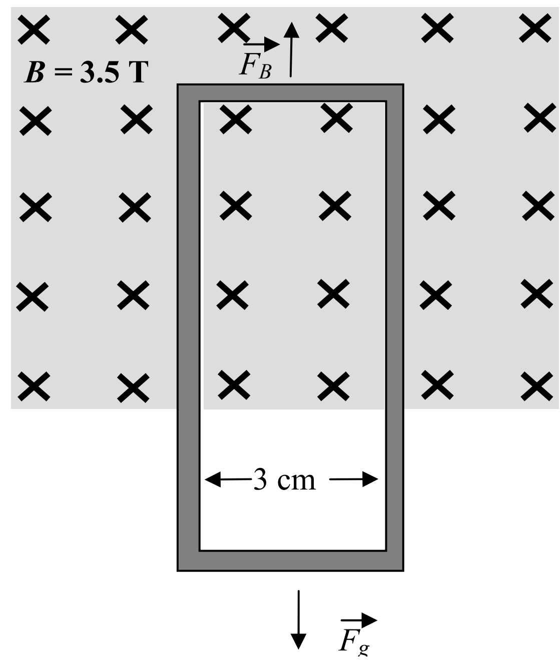
(b) What is the contribution, dE_x, to the *x* component of the electric field at the origin due to the charge *dq* in a segment *ds* at angle θ? (Hint: think about how to write *dq* in terms of the radius of the segment and the angle, $d\theta$ subtended by the segment *ds*.)

(c) What is the *x*-component, E_x, of the total electric field at the origin due to the entire charged ring segment (from $\theta_1 = -50^\circ$ to $\theta_2 = +50^\circ$)? Be sure to indicate the sign.



[14] 11. A rectangular loop of wire with a width of 3.0 cm and a mass of 0.17 kg falls from a region of uniform magnetic field with its long edges vertical as shown. The **total** resistance of the wire in the loop is 0.5 Ω. The magnitude of the field is 3.5 T and it points perpendicular to the plane of the loop as shown. For the period of time when the top edge of the loop is inside the region of uniform magnetic field and the bottom edge is outside, the loop falls with constant speed.

(a) What is the magnitude of the magnetic force, F_B, on the rectangular loop while it is falling at constant speed?



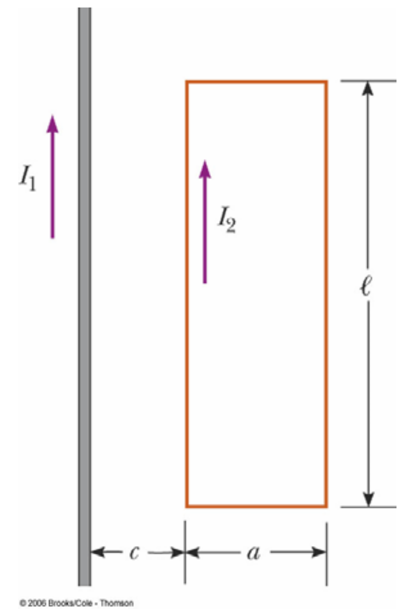
(b) What current must be induced in the loop in order to generate the magnetic force F_B? (Hint: think about which edge of the loop is acted on by the magnetic force.)

(c) At what constant speed does the loop drop while its upper edge is in the magnetic field and its lower edge is outside? (Hint: determine the *emf* necessary to drive the current found in (b) and then relate that to the speed using Faraday's law of induction.)

(d) In what direction (clockwise or counterclockwise) does the current flow in the loop as it is dropping out of the region of magnetic field?

Name:___________________________
Lab period: _____________ Student Number:_______________________

[14] 12. A long straight wire carrying a current $I_1 = 4.5\ \mathrm{A}$ lies in the plane of a rectangular loop which carries a current $I_2 = 3.7\ \mathrm{A}$. Referring to the figure, the dimensions of the loop are $l = 1.12\ \mathrm{m}$ and $a = 0.33\ \mathrm{m}$. The distance between the left edge of the loop and the long wire is $c = 0.22\ \mathrm{m}$.



(a) On the diagram, show the directions of the average magnetic forces on each of the sides of the loop caused by the magnetic field created by current I_1 in the long wire.

(b) Calculate the magnitude of the force on the left side of the loop (i.e. closest to the long wire) caused by the magnetic field created by current I_1 in the long wire.

(c) Calculate the net force (magnitude and direction) on the loop due to the magnetic field created by current I_1 in the long wire.

(d) Calculate the magnetic moment of the loop and indicate its direction (left, right, up, down, into the page, or out of the page).

(e) What is the net torque on the loop due to the magnetic field created by the long wire?

Name:__________________________
Lab period: _____________ Student Number:______________________

Some Potentially Useful Formulae:

$$\frac{d^2x}{dt^2} = -\omega^2 x$$
$$k = \frac{2\pi}{\lambda}$$
$$\omega = \frac{2\pi}{T}$$
$$v = f\lambda$$
$$\omega^2 = \frac{k_{\text{spring}}}{m}$$
$$\omega^2 = \frac{g}{L}$$
$$\omega^2 = \frac{mgd}{I}$$
$$v = \sqrt{\frac{T}{\mu}}$$
$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

$$\vec{F}_{12} = k_e \frac{q_1 q_2}{r^2}\hat{r}_{12}$$
$$\vec{E} = k_e \frac{q}{r^2}\hat{r}$$
$$\vec{E} = k_e \sum_i \frac{q_i}{r_i^2}\hat{r}_i$$
$$\vec{E} = k_e \int \frac{dq}{r^2}\hat{r}$$
$$\Phi_E = \int \vec{E}\cdot d\vec{A}$$
$$\Phi_E = \frac{q_{\text{inside}}}{\varepsilon_0}$$
$$V = k_e \frac{q}{r}$$
$$V = k_e \sum_i \frac{q_i}{r_i}$$
$$V = k_e \int \frac{dq}{r}$$

$$U_{12} = k_e \frac{q_1 q_2}{r_{12}}$$
$$\Delta U = -q\int_A^B \vec{E}\cdot d\vec{s}$$
$$\Delta U = q\Delta V$$
$$R = \frac{\Delta V}{I}$$
$$R = \rho\frac{l}{A}$$
$$\vec{F}_B = q\vec{v}\times\vec{B}$$
$$\vec{F}_B = I\vec{l}\times\vec{B}$$
$$\vec{\mu} = I\vec{A}$$
$$\vec{\tau} = \vec{r}\times\vec{F}$$
$$\vec{\tau} = \vec{\mu}\times\vec{B}$$
$$B = \frac{\mu_0 I}{2\pi a}$$

$$d\vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{s}\times\hat{r}}{r^2}$$
$$\frac{F_1}{l} = \frac{\mu_0 I_1 I_2}{2\pi a}$$
$$\oint \vec{B}\cdot d\vec{s} = \mu_0 I$$
$$\Phi_B = \int \vec{B}\cdot d\vec{A}$$
$$\varepsilon = -N\frac{d\Phi_B}{dt}$$
$$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$$
$$E_{\max} = cB_{\max}$$
$$\Delta\phi = \left(\frac{2\pi}{\lambda}\right)\delta$$
$$\delta = d\sin\theta$$
$$n = \frac{c}{v}$$

$$\Delta V = V_B - V_A = -\int_A^B \vec{E}\cdot d\vec{s}$$

$$\vec{E} = -\left(\frac{dV}{dx}\hat{i} + \frac{dV}{dy}\hat{j} + \frac{dV}{dz}\hat{k}\right)$$

$$d\sin\theta_{\text{bright}} = m\lambda \quad (m = 0,1,2\ldots)$$

Equations of Electromagnetism (Maxwell's Equations):

$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{\text{inside}}}{\varepsilon_0}$$
$$\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$
$$\oint \vec{B}\cdot d\vec{A} = 0$$
$$\oint \vec{B}\cdot d\vec{s} = \mu_0 I + \mu_0\varepsilon_0\frac{d\Phi_E}{dt}$$

Physical constants:

$k_e = \frac{1}{4\pi\varepsilon_0} = 8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$

$\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$

$\mu_0 = 4\pi\times10^{-7}\ \text{T}\cdot\text{m}/\text{A}$

$e = 1.602\times10^{-19}\ \text{C}$

$m_e = 9.11\times10^{-31}\ \text{kg}$

$c = 2.99\times10^8\ \text{m/s}$

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

Mathematical formulae

$$\vec{A}\cdot\vec{B} = AB\cos\theta = A_xB_x + A_yB_y + A_zB_z$$

$$\left|\vec{A}\times\vec{B}\right| = AB\sin\theta$$

$$\hat{i}\times\hat{j} = \hat{k} \quad \hat{j}\times\hat{k} = \hat{i} \quad \hat{k}\times\hat{i} = \hat{j}$$

$$\vec{A}\times\vec{B} = \left(A_yB_z - A_zB_y\right)\hat{i} + \left(A_zB_x - A_xB_z\right)\hat{j} + \left(A_xB_y - A_yB_x\right)\hat{k}$$

Roots of $ax^2 + bx + c = 0$ are:

$$x = \frac{-b\pm\sqrt{b^2 - 4ac}}{2a}$$

$$\int \frac{dx}{\left(x^2 + a^2\right)^{3/2}} = \frac{x}{a^2\sqrt{x^2 + a^2}}$$

$$\int \frac{x\,dx}{\left(x^2 + a^2\right)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}}$$

$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\tan^{-1}\frac{x}{a}$$

$$\int \frac{dx}{x^2} = -\frac{1}{x}$$

$$\int \frac{dx}{x} = \ln x$$