Circle instructor: Yethiraj or Morrow Name:___________________________
Lab period: _____________ Student Number:______________________

MEMORIAL UNIVERSITY OF NEWFOUNDLAND
DEPARTMENT OF PHYSICS AND PHYSICAL OCEANOGRAPHY

Final Exam **Physics 1051 Winter 2010** 3:00-5:00 April 15, 2010

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:

1	
2	
3	
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5	
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8	
9	
10	
11	
12	
TOTAL	

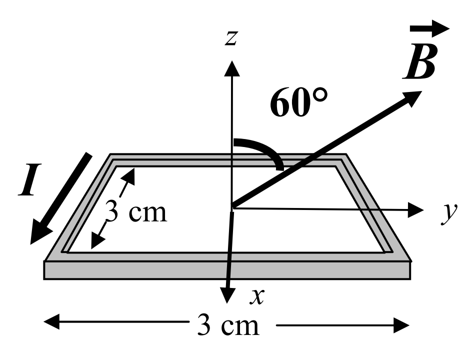
SECTION 1: There are 6 *SHORT ANSWER* questions. Each is worth 6 marks for a maximum of 36 marks. Budget time accordingly.

[6] 1. A scientist on a ship observes that a particular sequence of waves can be described by the function $y(x,t) = (0.800\text{ m})\cdot\sin[(0.628\text{ m}^{-1})\cdot\{x-(1.20\text{ m/s})t\}]$.
(a) At what speed do these waves travel?
(b) What is the wavelength?
(c) What is the period of these waves?

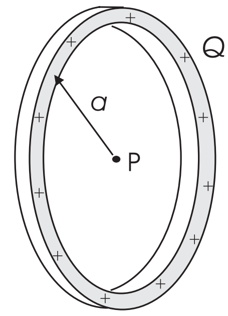
[6] 2. A square loop of wire with an area of 9 cm^2 is situated in the x-y plane. A current of 0.75 A circulates counterclockwise through the loop as shown below. A 1.4 T magnetic field is oriented at 60° from the z-axis in the y-z plane.

(a) What is the magnetic moment of the loop? Give your answer in unit vector notation.

(b) What is the magnitude of the magnetic torque on the loop?



[6] 3. A charge of $Q = +6.0 \times 10^{-6}$ C is uniformly distributed over a ring of radius $a = 4.5$ cm .



(a) What is the electric field at the centre of the ring?

(b) What is the electric potential at the centre of the ring?

(c) How much work would you need to do to slowly pull an electron from the centre of the ring to a point infinitely far away?

[6] 4. The electric potential in a region of space is given by $V = axy$ where $a = 1.7$ V/m^2.

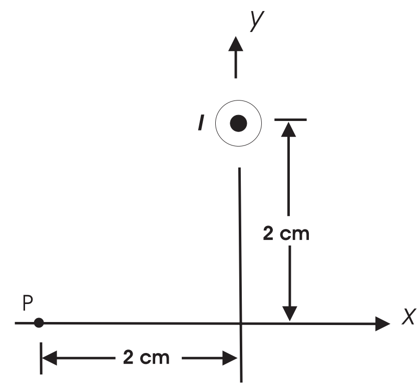
(a) What is the electric field at the point $x = 3.5$ m, $y = 2.0$ m? Give your answer in unit vector notation.

(b) If a particle of mass $m = 1.67 \times 10^{-27}$ kg and charge $q = +1.6 \times 10^{-19}$ C is released from this point, what is the magnitude of its initial acceleration?

[6] 5. A wire is located at $x = 0$, $y = 2.0$ cm and carries a current of $I = 0.75$ A out of the page (parallel to the z axis) as shown. Point P is located at $x = -2.0$ cm, $y = 0$ as shown.

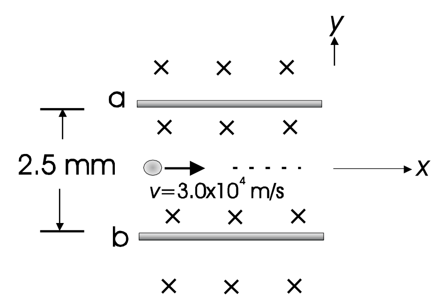
(a) On the diagram, draw a vector showing the direction of the magnetic field at point P due to the wire.

(b) What is the magnetic field at point P due to the wire? Give your answer in unit vector notation.



[6] 6. A uniform magnetic field of 13 T is directed into the page as shown. Two oppositely charged plates, **a** and **b**, are separated by 2.5 mm and located so that the uniform electric field between them is perpendicular to the magnetic field.

While it is between the charged plates, an ion with a charge of $+e$ (1.6×10^{-19} C), a mass of 1.6×10^{-25} kg and a speed of 3.0×10^{4} m/s travels in a straight line without being deflected.

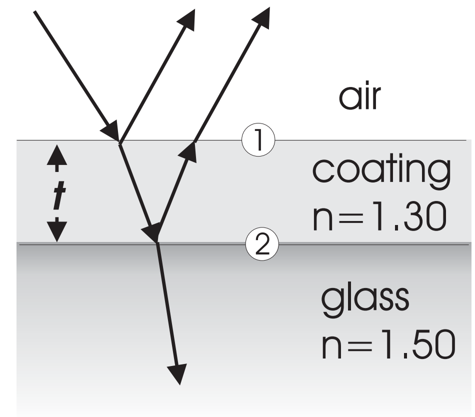


(a) What is the electric field in the region between the plates? Give your answer in unit vector notation.

(b) What is the potential difference, $V_b - V_a$, between the charged plates?

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

[12] 7. (a) A material having an index of refraction $n = 1.30$ is used as an antireflective coating on glass with an index of refraction $n = 1.50$ as shown.



(i) What is the phase shift for the reflection at the interface between air and the coating (interface 1)?

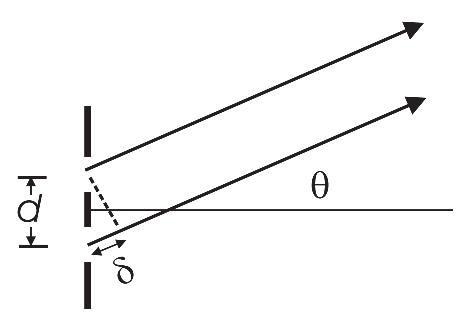
(ii) What is the phase shift for the reflection at the interface between the coating and the glass (interface 2)?

(iii) What minimum thickness must the coating have in order to minimize reflection of light with wavelength $\lambda = 555$ nm?

(b) In the diagram below, light with a wavelength of 600 nm is incident on a barrier with two small slits separated by a distance $d = 4.5 \times 10^{-6}$ m. The two (nearly) parallel rays drawn converge at a spot on a distant screen. The angle between the rays and the axis is θ.

(i) In terms of d and θ, what is the what is the difference in length, δ, between the paths from the two slits to the spot on the screen?

(ii) If the spot on the screen where the waves meet is the dark spot closest to the centre of the interference pattern, what is the angle θ?



[12] 8. (a) (i) In terms of the length L and the speed of sound v, what is the difference in frequency between the first two resonances of a tube that is open at one end and closed at the other?

(ii) An artist building a sound sculpture needs a tube open at one end and closed at the other that resonates at a series of frequencies **separated** by 256 Hz. She can assume that the speed of sound is 343 m/s. What is the tube's fundamental frequency?

(iii) How long should the tube be?

(b) Two strings of equal length, L, are each clamped at both ends and are under the same tension T. String 1 has a mass of 45.00 g and vibrates at a frequency of 512 Hz. String 2 is slightly heavier. When the two strings are plucked at the same time, beats with a frequency of 4.0 Hz are heard.

(i) What is the vibrational frequency of string 2?

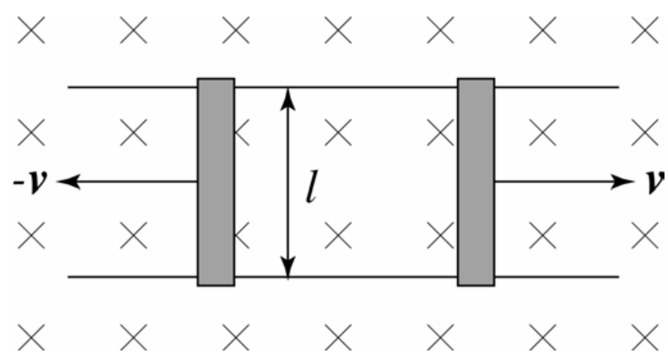
(ii) What is the mass of string 2?

[12] 9. Two sliding metal bars of length l = 15.0 cm are moving along two parallel rails, in opposite directions, with constant speeds of v = 0.7 m/s, as shown in the figure below. The rails are located in a uniform magnetic field with a magnitude 0.35 T that is directed into the page as shown.

(a) Calculate the rate of change of magnetic flux within the loop formed by the sliders and the rails.

(b) In what direction does the induced current flow around the loop? Indicate this clearly on the diagram and briefly justify your answer.

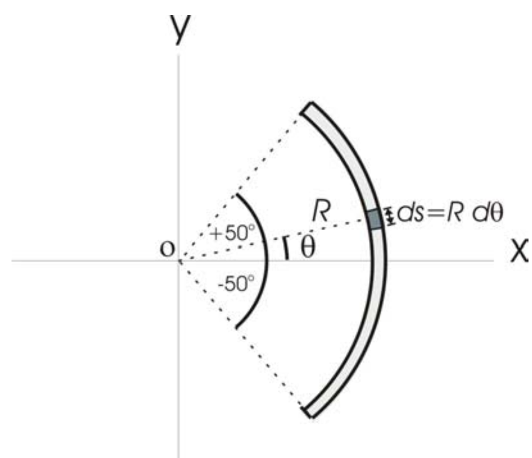
(c) If that current is 0.25 A, calculate the total resistance of the loop.



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.

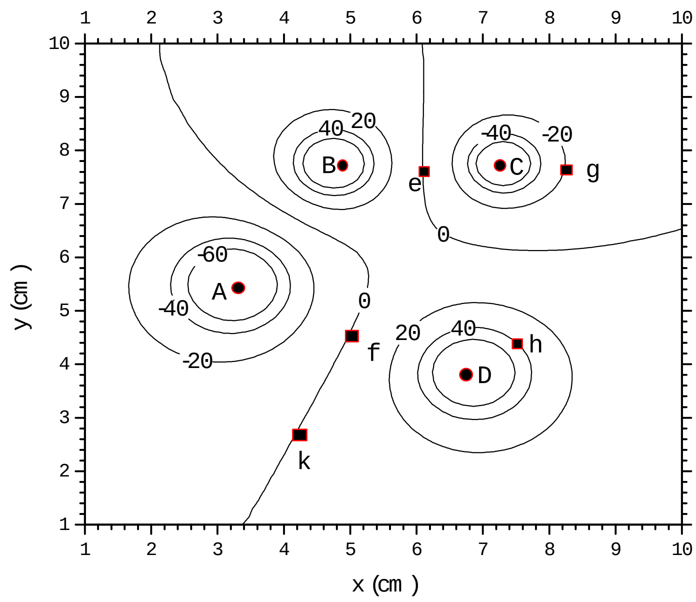
(a) Without doing an integral, what is the *y*-component, E_y, of the total electric field at the origin due to the entire charged ring segment (from $\theta_1 = -50^\circ$ to $\theta_2 = +50^\circ$)?



(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) Equipotential lines around four point charges are drawn in steps of 20 V for all voltages between -60 V and +60 V as shown. Electric potential is taken to be 0 at infinity.

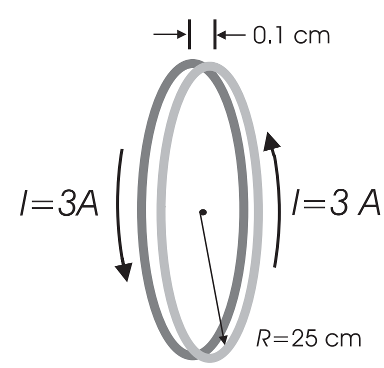


(i) Carefully draw the electric field line, including direction, that starts on one charge, passes through point **k**, and ends on another charge.

(ii) Use the scale on the *x*-axis and the equipotentials, estimate the magnitude of the electric field at point **e**.

(iii) How much work would be done by the electric field if a charge $q = -5\ \mu C$ was moved from point **h** to point **g**? Be careful with the sign.

(b) Consider two circular rings, each of radius $R = 25.0$ cm, separated by 0.10 cm as shown. Each ring carries a current $I = 3.0$ A. What is the magnitude of the force exerted on one ring by the other ring?



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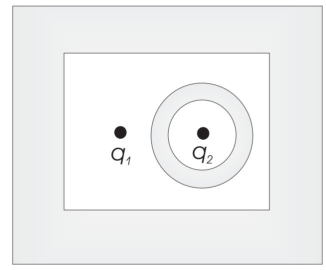
[14] 12. (a) An uncharged box with thick conducting sides contains two charges, $q_1 = 6\ \mu\text{C}$ and $q_2 = 6\ \mu\text{C}$. Charge q_2 is enclosed by an uncharged spherical conducting shell as shown.

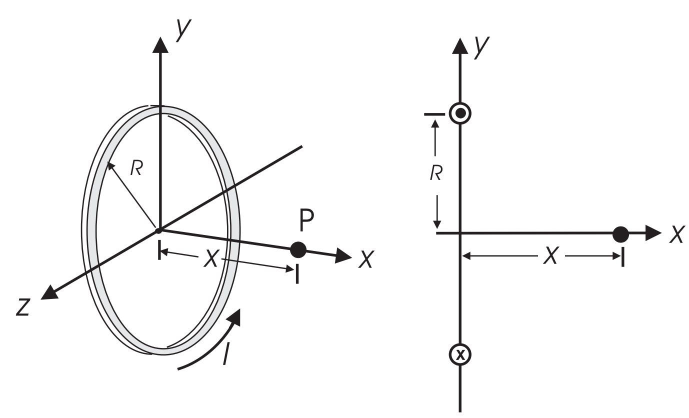


(i) What is the total charge on the inside surface of the box?

(ii) What is the total charge on the outside surface of the box?

(iii) Where on the outside surface of the box would you expect to find the highest surface charge density?

(b) A thin circular loop of radius R is centred on the origin and oriented so that it is perpendicular to the x-axis as shown. It carries a current I as shown. Write an expression for the magnetic field at point P located a distance x from the centre of the ring along the x-axis. For your convenience, a cross-section drawing of the ring looking from the z – axis is provided.



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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):

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

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

$$\vec{A}\cdot\vec{B} = AB\cos\theta = A_xB_x + A_yB_y + A_zB_z$$
$$\left|\vec{A}\times\vec{B}\right| = AB\sin\theta$$
$$\hat{i}\times\hat{j} = \hat{k} \quad \hat{j}\times\hat{k} = \hat{i} \quad \hat{k}\times\hat{i} = \hat{j}$$
$$\vec{A}\times\vec{B} = (A_yB_z - A_zB_y)\hat{i} + (A_zB_x - A_xB_z)\hat{j} + (A_xB_y - A_yB_x)\hat{k}$$

Roots of $ax^2 + bx + c = 0$ are:
$$x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

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