PHY 2049C Exam III Fall 2016

Name________________________________VID________________________________

Make sure to show all of your work neatly and organized with your final answers circled or underlined. Also don't forget units on your final answers if you wish to recieve full credit! Good luck!

1) A parallel–plate capacitor consists of two parallel, square plates that have dimensions 1.0 cm by 1.0 cm. The plates are separated by 0.1 mm, and the space between them is filled with teflon. (The dielectric constant for teflon is 2.1, and $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$.)

(a) What is the capacitance with the dielectric inserted.

(b) If a constant potential difference of 80 V is held across the capacitor, how much energy is stored in it?

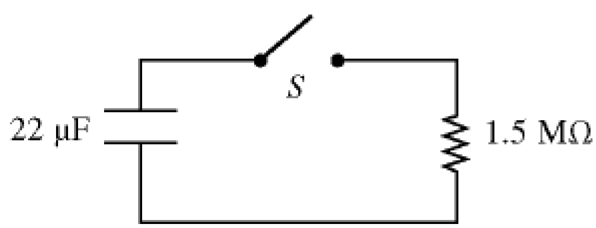
(c) What would the total capacitance be if only the left half of the vertically oriented capacitor was filled with dielectric?

2) For the circuit shown in the figure, the switch S is initially open and the capacitor voltage is 80 V. The switch is then closed at time $t = 0$.

(a) What is the current in the circuit at t = 0?

(b) What is the charge on the capacitor when the current in the circuit is 33 μA?

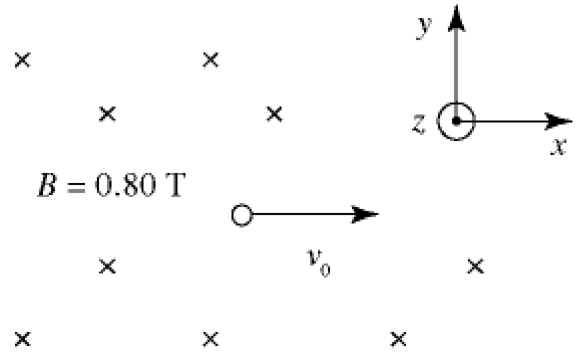
(c) How long after the switch is closed does this occur?



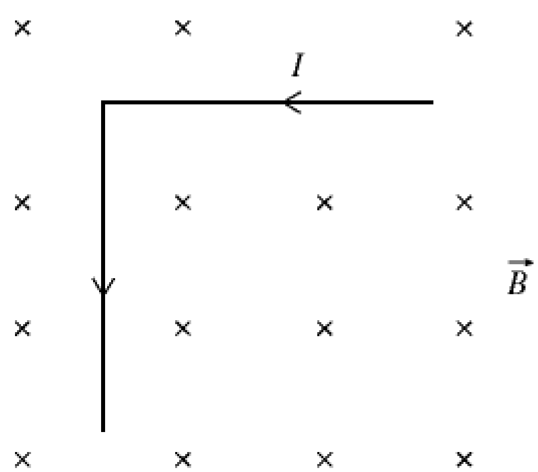
3) A uniform magnetic field of magnitude 0.80 T in the negative z–direction is present in a region of space, as shown in the figure. A uniform electric field is also present. An electron that is projected with an initial velocity $v_0 = 9.1 \times 10^4$ m/s in the positive x–direction passes through the region without deflection.

(a) What is the magnitude of the electric field vector in the region?

(b) What is the direction of the electric field vector in the region?



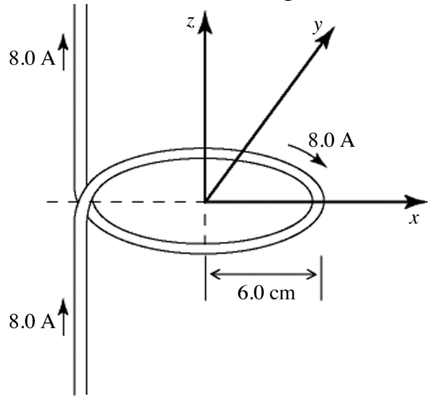
4) An L–shaped metal machine part is made of two equal–length segments that are perpendicular to each other and carry a 4.50–A current as shown in the figure. This part has a total mass of 3.80 kg and a total length of 3.00 m, and it is in an external 1.20–T magnetic field that is oriented perpendicular to the plane of the part, as shown. What is the magnitude and direction of the NET magnetic force that the field exerts on the part?



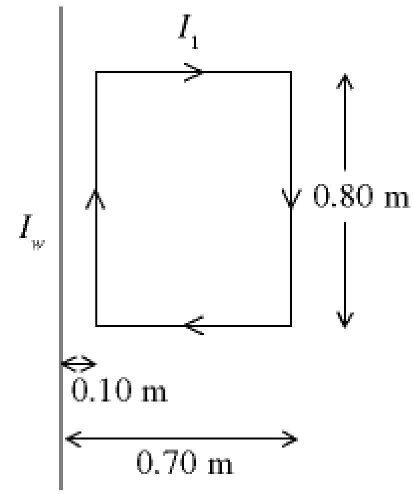
5) As shown in the figure, an insulated wire is bent into a circular loop of radius 6.0 cm and has two long straight sections. The loop is in the xy-plane, with the center at the origin. The straight sections are parallel to the z-axis. The wire carries a current of 8.0 A. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

(a) What is the y-component of the magnetic field at the origin?

(b) What is the NET magnetic field (magnitude and direction)?



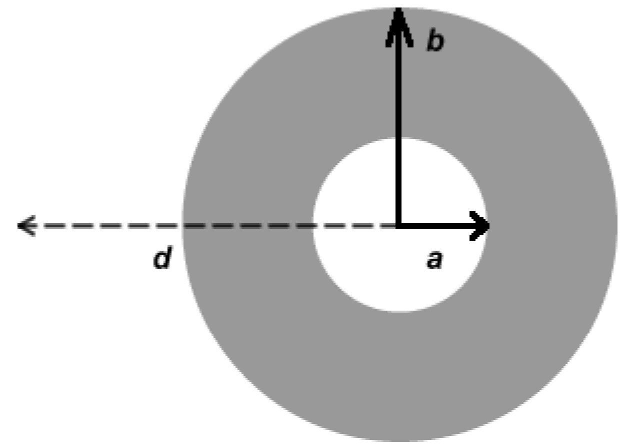
6) As shown in the figure, a rectangular current loop is carrying current $I_1 = 3.0$ A, in the direction shown, and is located near a long wire carrying a current I_w. The long wire is parallel to the sides of the rectangle. The rectangle loop has length 0.80 m and its sides are 0.10 m and 0.70 m from the wire, as shown. We measure that the net force on the rectangular loop is 4.9×10^{-6} N and is directed towards the wire.
($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)
(a) What is the magnitude of the current I_w?
(b) In which direction does I_w flow: from top to bottom or from bottom to top in the sketch?



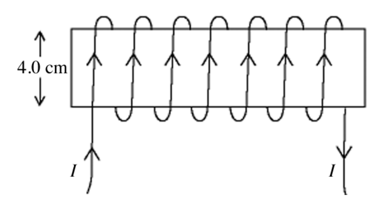
7) The figure shows the cross–section of a hollow cylinder of inner radius $a = 5.0$ cm and outer radius $b = 7.0$ cm. A uniform current density of 1.0 A/ cm^2 flows through the cylinder parallel to its axis. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

(a) What is the magnitude of the magnetic field at a distance the distance a from the axis?

(b) What is the magnitude of the magnetic field at a distance of $d = 10$ cm from the axis of the cylinder.



8) A solenoid is wound with 970 turns on a form 4.0 cm in diameter and 50 cm long. The windings carry a current I in the sense that is shown in the figure. The current produces a magnetic field, of magnitude 4.3 mT, near the center of the solenoid. Find the current in the solenoid windings. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



ormula Sheet

laxwell's Equations:

$$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{\text{encl}}}{\epsilon_0} \quad \text{(Gauss's law for } \vec{E}\text{)}$$

$$\oint \vec{B}\cdot d\vec{A} = 0 \quad \text{(Gauss's law for } \vec{B}\text{)}$$

$$\oint \vec{B}\cdot d\vec{l} = \mu_0\left(i_C + \epsilon_0 \frac{d\Phi_E}{dt}\right)_{\text{encl}} \quad \text{(Ampere's law)}$$

$$\oint \vec{E}\cdot d\vec{l} = -\frac{d\Phi_B}{dt} \quad \text{(Faraday's law)}$$

orrentz Force Law:

$$\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$$

tanding Waves:

$$f_n = n\frac{\upsilon}{2L} = nf_1 \quad (n = 1,2,3,\ldots)$$

oppler effect:

$$f_L = \frac{\upsilon + \upsilon_L}{\upsilon + \upsilon_S} f_S$$

lechanical Waves:

$$\upsilon = \lambda f \quad \text{(periodic wave)}$$

$$y(x,t) = A\cos\left[\omega\left(\frac{x}{\upsilon} - t\right)\right] = A\cos\left[2\pi f\left(\frac{x}{\upsilon} - t\right)\right] \quad \text{(sinusoidal w}$$

$$y(x,t) = A\cos\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right] \quad \text{(sinusoidal wave movin}$$

$$y(x,t) = A\cos(kx - \omega t) \quad \text{(sinusoidal wave moving ir}$$

$$\frac{\partial^2 y(x,t)}{\partial x^2} = \frac{1}{\upsilon^2}\frac{\partial^2 y(x,t)}{\partial t^2} \quad \text{(wave equation)}$$

$$\upsilon = \sqrt{\frac{F}{\mu}} \quad \text{(speed of a transverse wave on a string)}$$

$$P_{\text{av}} = \frac{1}{2}\sqrt{\mu F}\,\omega^2 A^2 \quad \text{(average power, sinusoidal wave on a string}$$

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2} \quad \text{(inverse-square law for intensity)}$$

$$y(x,t) = y_1(x,t) + y_2(x,t) \quad \text{(principle of superposition)}$$

Electric Field:

$$F = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2} \quad \text{(Coulomb's law: force between two point cha}$$

$$\vec{E} = \frac{\vec{F}_0}{q_0} \quad \text{(definition of electric field as electric force per unit cha}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r} \quad \text{(electric field of a point charge)}$$

$$\tau = pE\sin\phi \quad \text{(magnitude of the torque on an electric dipole}$$

$$\vec{\tau} = \vec{p}\times\vec{E} \quad \text{(torque on an electric dipole, in vector form)}$$

$$U = -\vec{p}\cdot\vec{E} \quad \text{(potential energy for a dipole in an electric field)}$$

lectric Potential:

$$W_{a\to b} = U_a - U_b = -(U_b - U_a) = -\Delta U$$ (work done by a conservative

$$U = \frac{1}{4\pi \epsilon_0}\frac{qq_0}{r}$$ (electric potential energy of two point charges q and q_0)

$$U = \frac{q_0}{4\pi \epsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \cdots\right) = \frac{q_0}{4\pi \epsilon_0}\sum_i \frac{q_i}{r_i}$$ (point charge q_0 and collectio

$$V = \frac{U}{q_0} = \frac{1}{4\pi \epsilon_0}\frac{q}{r}$$ (potential due to a point charge)

$$V = \frac{U}{q_0} = \frac{1}{4\pi \epsilon_0}\sum_i \frac{q_i}{r_i}$$ (potential due to a collection of point charge)

$$V = \frac{1}{4\pi \epsilon_0}\int \frac{dq}{r}$$ (potential due to a continuous distribution of charg

$$V_a - V_b = \int_a^b \vec{E}\cdot d\vec{l} = \int_a^b E\cos\phi\, dl$$ (potential difference as an integ

$$E_x = -\frac{\partial V}{\partial x} \qquad E_y = -\frac{\partial V}{\partial y} \qquad E_z = -\frac{\partial V}{\partial_z}$$ (components of $\vec{E}$ in te

$$\vec{E} = -\left(\hat{i}\frac{\partial V}{\partial x} + \hat{j}\frac{\partial V}{\partial y} + \hat{k}\frac{\partial V}{\partial z}\right)$$ ($\vec{E}$ in terms of V)

apacitance:

$$C = \frac{Q}{V_{ab}}$$ (definition of capacitance)

$$C = \frac{Q}{V_{ab}} = \epsilon_0 \frac{A}{d}$$ (capacitance of a parallel-plate capacitor in vacuum)

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$ (capacitors in series)

$$C_{eq} = C_1 + C_2 + C_3 + \ldots$$ (capacitors in parallel)

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$ (potential energy stored in a capacitor)

$$u = \frac{1}{2}\epsilon_0 E^2$$ (electric energy density in a vacuum)

Current, Resistance, and Ohm's Law

$$I = \frac{dQ}{dt} = n|q|\upsilon_d A$$ (general expression for current)

$$\vec{J} = nq\vec{\upsilon}_d$$ (vector current density)

$$\rho = \frac{E}{J}$$ (definition of resistivity)

$$\rho(T) = \rho_0[1 + \alpha(T - T_0)]$$ (temperature dependence of re

$$R = \frac{\rho L}{A}$$ (relationship between resistance and resistiv

$$V = IR$$ (relationship among voltage, current, and resis

$$V_{ab} = \varepsilon - Ir$$ (terminal voltage, source with internal resi

$$P = V_{ab}I$$ (rate at which energy is delivered to or extracted from a ci

$$P = V_{ab}I = I^2R = \frac{V_{ab}^2}{R}$$ (power delivered to a resistor

$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$ (resistors in series)

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$ (resistors in parallel)

$$\sum I = 0$$ (junction rule, valid at any junction)

$$\sum V = 0$$ (loop rule, valid for any closed loop)

$$q = C\varepsilon(1 - e^{-t/RC}) = Q_f(1 - e^{-t/RC})$$ (R-C circuit, charging cap

$$i = \frac{dq}{dt} = \frac{\varepsilon}{R}e^{-t/RC} = I_0 e^{-t/RC}$$ (R-C circuit, charging capacit

$$q = Q_0 e^{-t/RC}$$ (R-C circuit, discharging capacitor)

$$i = \frac{dq}{dt} = -\frac{Q_0}{RC}e^{-t/RC} = I_0 e^{-t/RC}$$ (R-C circuit, discharging cap

Magnetic Force and Magnetic Flux:

$\vec{F} = q\vec{v} \times \vec{B}$ (magnetic force on a moving charged particle)

$\Phi_B = \int B_\perp \, dA = \int B\cos\phi \, dA = \int \vec{B} \cdot d\vec{A}$ (magnetic flux through a surface)

$\oint \vec{B} \cdot d\vec{A} = 0$ (magnetic flux through any closed surface)

$R = \dfrac{mv}{|q|B}$ (radius of a circular orbit in a magnetic field)

$\vec{F} = I\vec{l} \times \vec{B}$ (magnetic force on a straight wire segment)

$d\vec{F} = I d\vec{l} \times \vec{B}$ (magnetic force on an infinitesimal wire section)

$\tau = IBA\sin\phi$ (magnitude of torque on a current loop)

$\vec{\tau} = \vec{\mu} \times \vec{B}$ (vector torque on a current loop)

$U = -\vec{\mu} \cdot \vec{B} = -\mu B\cos\phi$ (potential energy for a magnetic dipole)

Magnetic Field:

$\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{q\vec{v} \times \hat{r}}{r^2}$ (magnetic field of a point charge with constant veloci

$d\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{I d\vec{l} \times \hat{r}}{r^2}$ (magnetic field of a current element)

$B = \dfrac{\mu_0 I}{2\pi r}$ (near a long, straight, current-carrying conductor)

$\dfrac{F}{L} = \dfrac{\mu_0 I I'}{2\pi r}$ (two long, parallel, current-carrying conductors)

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{encl}}$$

Volume and Area Formulae:

Circle:

Area:	πr^2
Circumference:	$2\pi r$

Sphere:

Area:	$4\pi r^2$
Volume:	$4/3\ \pi r^3$

Cylinder:

Area:	$2\pi rl$
Volume:	$\pi r^2 l$

Fundamental Constants:

$c = 2.9979 \bullet 10^8$ m/s

$k = 9.0 \bullet 10^9\ Nm^2/C^2$

$\varepsilon_0 = 4\pi/k = 8.85 \cdot 10^{-12}\ C^2/Nm^2$

$\mu_0 = 4\pi \cdot 10^{-7}$ TA/m

$q_e = 1.602 \cdot 10^{-19}$ C

$m_e = 9.11 \cdot 10^{-30}$ kg