Official Starting Equations
PHYS 2135, Engineering Physics II

From PHYS 1135:

$x = x_0 + v_{0x}\Delta t + \frac{1}{2}a_x(\Delta t)^2$ $\quad v_x = v_{0x} + a_x\Delta t$ $\quad v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ $\quad \sum \vec{F} = m\vec{a}$

$F_r = -\frac{mv_t^2}{r}$ $\quad P = \frac{F}{A}$ $\quad \vec{p} = m\vec{v}$ $\quad P = \frac{dW}{dt}$ $\quad W = \int \vec{F} \cdot d\vec{s}$

$K = \frac{1}{2}mv^2$ $\quad U_f - U_i = -W_{\text{conservative}}$ $\quad E = K + U$ $\quad E_f - E_i = (W_{\text{other}})_{i \to f}$ $\quad E = P_{\text{ave}}t$

Constants:

$g = 9.8\,\frac{\text{m}}{\text{s}^2}$ $\quad m_{\text{electron}} = 9.11 \times 10^{-31}\text{kg}$ $\quad m_{\text{proton}} = 1.67 \times 10^{-27}\text{kg}$ $\quad e = 1.6 \times 10^{-19}\text{C}$

$c = 3.0 \times 10^8\,\frac{\text{m}}{\text{s}}$ $\quad k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\frac{\text{Nm}^2}{\text{C}^2}$ $\quad \epsilon_0 = 8.85 \times 10^{-12}\,\frac{\text{C}^2}{\text{Nm}^2}$ $\quad \mu_0 = 4\pi \times 10^{-7}\,\frac{\text{Tm}}{\text{A}}$

Electric Force, Field, Potential and Potential Energy:

$\vec{F} = k\frac{q_1q_2}{r_{12}^2}\hat{r}_{12}$ $\quad \vec{E} = k\frac{q}{r^2}\hat{r}$ $\quad \vec{F} = q\vec{E}$ $\quad \Delta V = -\int_i^f \vec{E} \cdot d\vec{s}$

$U = k\frac{q_1q_2}{r_{12}}$ $\quad V = k\frac{q}{r}$ $\quad \Delta U = q\Delta V$ $\quad E_x = -\frac{\partial V}{\partial x}$

$\vec{p} = q\vec{d}$ (from – to +) $\quad \vec{\tau} = \vec{p} \times \vec{E}$ $\quad U_{\text{dipole}} = -\vec{p} \cdot \vec{E}$

$\Phi_E = \int_S \vec{E} \cdot d\vec{A}$ $\quad \oint_S \vec{E} \cdot d\vec{A} = \frac{q_{\text{enclosed}}}{\epsilon_0}$ $\quad \lambda \equiv \frac{\text{charge}}{\text{length}}$ $\quad \sigma \equiv \frac{\text{charge}}{\text{area}}$ $\quad \rho \equiv \frac{\text{charge}}{\text{volume}}$

Circuits:

$C = \frac{Q}{V}$ $\quad \frac{1}{C_T} = \sum \frac{1}{C_i}$ $\quad C_T = \sum C_i$ $\quad C_0 = \frac{\epsilon_0 A}{d}$ $\quad C = \kappa C_0$

$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV$ $\quad I = \frac{dq}{dt}$ $\quad J = \frac{I}{A}$ $\quad \vec{J} = nq\vec{v}_d$

$\vec{J} = \sigma\vec{E}$ $\quad V = IR$ $\quad R = \rho\frac{L}{A}$ $\quad \sigma = \frac{1}{\rho}$ $\quad \rho = \rho_0[1 + \alpha(T - T_0)]$

$\sum I = 0$ $\quad \sum \Delta V = 0$ $\quad \frac{1}{R_T} = \sum \frac{1}{R_i}$ $\quad R_T = \sum R_i$ $\quad P = IV = \frac{V^2}{R} = I^2R$

$Q(t) = Q_{\text{final}}\left[1 - e^{-t/\tau}\right]$ $\quad Q(t) = Q_0e^{-t/\tau}$ $\quad \tau = RC$

Integral:

$$\int \frac{du}{(u^2+a^2)^{3/2}} = \frac{u}{a^2\sqrt{u^2+a^2}} + c$$

Magnetic Force, Field and Inductance:

$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$ $\quad$ $\vec{F} = I\vec{L} \times \vec{B}$ $\quad$ $\Phi_B = \int \vec{B} \cdot d\vec{A}$ $\quad$ $\oint \vec{B} \cdot d\vec{A} = 0$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enclosed}}$ $\quad$ $\vec{\mu} = NI\vec{A}$ $\quad$ $\vec{\tau} = \vec{\mu} \times \vec{B}$ $\quad$ $U_{\text{dipole}} = -\vec{\mu} \cdot \vec{B}$

$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$ $\quad$ $d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2}$ $\quad$ $\mathcal{E} = -N \frac{d\Phi_B}{dt}$ $\quad$ $\oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt}$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enclosed}} + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$ $\quad$ $B = \frac{\mu_0 I}{2\pi r}$ $\quad$ $B = \mu_0 n I$

Electromagnetic Waves:

$I = \frac{P}{A}$ $\quad$ $u = \frac{1}{2}\left(\epsilon_0 E^2 + \frac{B^2}{\mu_0}\right) = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$ $\quad$ $\langle u \rangle = \frac{1}{4}\left(\epsilon_0 E_{\max}^2 + \frac{B_{\max}^2}{\mu_0}\right) = \frac{1}{2}\epsilon_0 E_{\max}^2 = \frac{B_{\max}^2}{2\mu_0}$

$\frac{E}{B} = c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$ $\quad$ $\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$ $\quad$ $I = \langle S \rangle = c\langle u \rangle$ $\quad$ $\langle P_{\text{rad}} \rangle = \frac{I}{c}$ or $\frac{2I}{c}$

$k = \frac{2\pi}{\lambda}$ $\quad$ $\omega = 2\pi f$ $\quad$ $T = \frac{1}{f}$ $\quad$ $v = f\lambda = \frac{\omega}{k} = \frac{c}{n}$

Optics:

$I = I_{\max} \cos^2 \phi$ $\quad$ $\theta_r = \theta_i$ $\quad$ $n = \frac{c}{v} = \frac{\lambda_0}{\lambda_n}$ $\quad$ $n_r \sin\theta_r = n_i \sin\theta_i$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ $\quad$ $m = \frac{y'}{y} = -\frac{s'}{s}$ $\quad$ $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $\quad$ $f = \frac{R}{2}$

$\frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R}$ $\quad$ $m = \frac{y'}{y} = -\frac{n_a s'}{n_b s}$ $\quad$ $\Delta L = m\lambda$ $\quad$ $\Delta L = \left(m + \frac{1}{2}\right)\lambda$

$\Delta L = d \sin\theta$ $\quad$ $\phi = 2\pi\left(\frac{\Delta L}{\lambda}\right)$ $\quad$ $I = I_0 \cos^2 \frac{\phi}{2}$ $\quad$ $R = \frac{\lambda}{\Delta\lambda} = Nm$

$m\lambda = a \sin\theta$ $\quad$ $\beta = \frac{2\pi}{\lambda} a \sin\theta$ $\quad$ $I = I_0 \left[\frac{\sin(\beta/2)}{\beta/2}\right]^2$

Integral:

$\int \frac{du}{(u^2+a^2)^{3/2}} = \frac{u}{a^2\sqrt{u^2+a^2}} + c$

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Exam Total
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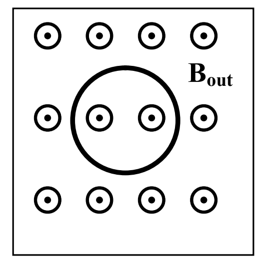
PHYS 2135 Exam III
November 15, 2022

Name: ______________________ Section: _________

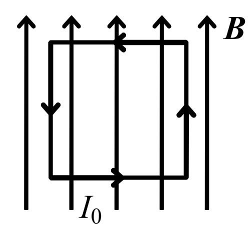
For questions 1-5, select the best answer. For problems 6-10, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed. Use appropriate units. Provide answers in terms of given variable and fundamental constants.

(8)____**C**____**1.** The way that electric generators produce electrical energy is best described by
[A] Ampère's Law
[B] Gauss' Law for magnetism
[C] Faraday's Law
[D] Biot-Savart Law

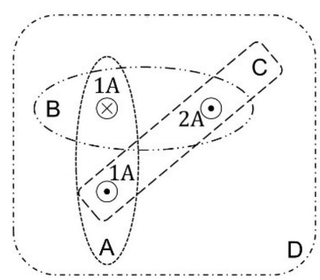
(8)____**D**____**2.** A single circular loop of wire is perpendicular to a uniform magnetic field $\mathbf{B}_{\mathbf{out}}$ directed out of the page as shown. If the magnitude of the field is *decreasing*, then the induced current in the wire is
[A] directed out of the page
[B] directed into the page
[C] clockwise around the loop
[D] counterclockwise around the loop



(8)____**A**____**3.** A square loop is placed in a uniform magnetic field directed upward. A constant current, I_0, is maintained in the loop. Which is true about the net force and net torque on the loop?
[A] the net force is zero, but there is a net torque
[B] there is a net force, but the net torque is zero
[C] there is a net force and a net torque
[D] the net force is zero and the net torque is zero



(8)____**C**____**4.** The wires shown carry the current indicated either into or out of the page. For which path is the magnitude of $\oint \vec{B} \cdot d\vec{l}$ greatest?
[A] A
[B] B
[C] C
[D] D



(8)__________**5.** (Free) In 1908, a giant explosion occurred at Tunguska (Siberia) that was estimated at between 10-15 megatons and felled approximately 6 million trees in an area over 2000 square kilometers. Some believe Nikola Tesla was responsible for the explosion. Most likely
[A] they are correct-never anger a physicist
[B] they are nutcases, it was obviously the result of a meteor or comet
[C] nope, nope, just UFOs having some fun
[D] it was really a miniature black hole that passed through the earth

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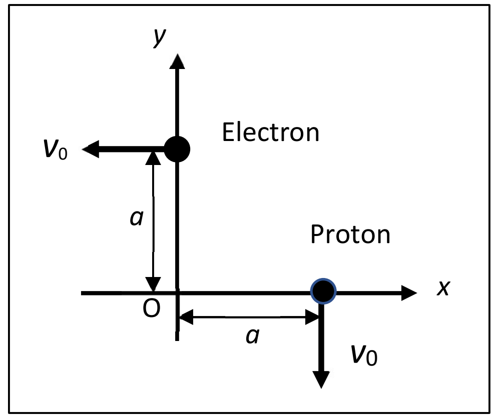
6. An electron is moving with a speed v_0 in the – *x* direction and a proton is moving with a speed v_0 in the – *y* direction. At a certain instant in time the electron is at $y = a$ and the proton is at $x = a$ as shown.



(5) a. Determine the direction of the magnetic field at the origin *O* due to the electron.

$-\hat{k}$

(5) b. Determine the direction of the magnetic field at the origin *O* due to the proton.

$-\hat{k}$

(5) c. Determine the direction of the magnetic field the electron produces at the location of the proton.

$-\hat{k}$

(10) d. Determine the <u>magnitude</u> of the magnetic field the electron produces at the proton.

$$B = \frac{\mu_0 e v_0}{8\sqrt{2}\pi a^2}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2} = \frac{\mu_0}{4\pi}\frac{ev_0(-\hat{\imath})}{2a^2}\times\frac{\hat{\imath}-\hat{\jmath}}{\sqrt{2}}$$

(5) e. Determine the magnetic force that the electron exerts on the proton. Use unit vector notation.

$$\vec{F} = \frac{\mu_0 e^2 v_0^2}{8\sqrt{2}\pi a^2}\hat{\imath}$$

$$\vec{F} = q\vec{v}\times\vec{B} = ev_0(-\hat{\jmath})\times\frac{\mu_0 e v_0}{8\sqrt{2}\pi a^2}(-\hat{k})$$

(10) f. Transmission lines can carry large currents. Some people have concerns that there may be health problems if these transmission lines are near their homes. Assume a line has a current of 140 A and the line is 8 m above the ground. Determine the ratio of the magnetic field produced by the line at the ground to the earth's magnetic field, which is $5 \times 10^{-5} T$. Give a numerical value.

$$\frac{B_L}{B_E} = 0.07$$

$$B_L = \frac{\mu_0 I}{2\pi} = \frac{(4\pi\times10^{-7}\mathrm{Tm/A})(140\mathrm{A})}{2\pi(8\mathrm{m})} = 35\times10^{-7}\mathrm{T}$$

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7. A long, straight, hollow cylindrical conductor of inner radius *a* and outer radius *b* > *a* carries a current I_0 along its length. The current is uniformly distributed throughout the cross section of the conductor. **In each region, begin with an appropriate law and derive the magnitude of the magnetic field in the region.**

(10) a. Calculate the magnitude of the magnetic field on the axis of the conductor (*r* = *0*).

$$\boxed{B = 0}$$

$$\oint \vec{B} \cdot d\vec{A} = \mu_0 I_{\text{enc}} = 0$$

(15) b. Calculate the magnitude of the magnetic field inside the conductor, at a distance *a* < *r* < *b* from the axis of the conductor.

$$\boxed{B = \frac{\mu_0 I_0 (r^2 - a^2)}{2\pi(b^2 - a^2) r}}$$

$$\oint \vec{B} \cdot d\vec{A} = \mu_0 I_{\text{enc}}$$

$$B(2\pi r) = \mu_0 I_0 \left(\frac{\pi r^2 - \pi a^2}{\pi b^2 - \pi a^2}\right)$$

(15) c Calculate the magnitude of the magnetic field outside the conductor, at a distance *r* > *b* from the axis of the conductor.

$$\boxed{B = \frac{\mu_0 I_0}{2\pi r}}$$

$$\oint \vec{B} \cdot d\vec{A} = \mu_0 I_{\text{enc}}$$

$$B(2\pi r) = \mu_0 I_0$$

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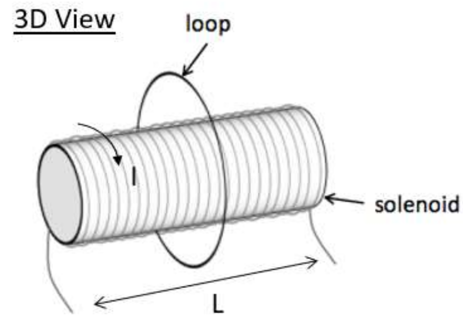
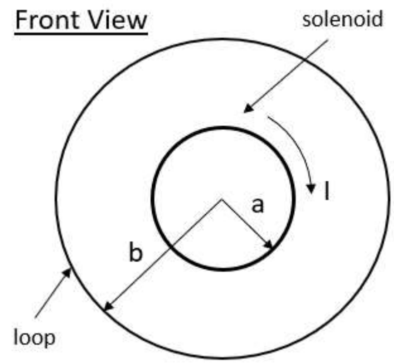
8. A loop of N_l turns, resistance *R*, and radius b is placed around a long solenoid of radius *a*, as shown in the figure. The solenoid has a length *L*, N_s turns, and is driven by a clockwise current $I = At^2$ with $A > 0$.





(10) a. What is the magnitude of the magnetic flux through the loop with respect to time? (Assume the magnetic field outside of the solenoid is zero)

$$\boxed{\Phi_B = \frac{\mu_0 N_s A t^2 \pi a^2}{L}}$$

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

$$\Phi_B = \left(\mu_0 \frac{N_s}{L} A t^2\right)(\pi a^2)$$

(10) b. What is the magnitude of the emf induced in the loop with respect to time?

$$\mathcal{E} = -N \frac{d}{dt} \Phi_B$$

$$\boxed{\mathcal{E} = \frac{2\mu_0 N_s N_l A t \pi a^2}{L}}$$

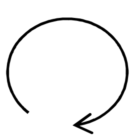
$$|\mathcal{E}| = N_l \frac{d}{dt}\left[\frac{\mu_0 N_s A t^2 \pi a^2}{L}\right]$$

(10) c. What is the magnitude of the induced current in the loop with respect to time?

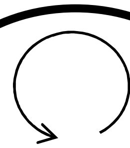
$$\boxed{I_I = \frac{2\mu_0 N_s N_l A t \pi a^2}{RL}}$$

$$I_I = \frac{\mathcal{E}}{R}$$

(10) d. What is the direction of the induced current in the loop (from the perspective of the front view)? Circle your answer.



Clockwise



Counter-clockwise

No induced current

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9. A radio tower broadcasts uniformly in all directions resulting in a magnetic field with amplitude B_0 at a distance d from the tower where there is a circular absorbing antenna of radius a facing the broadcast tower.

(10) a. Determine the total power of the radio broadcast.

$$\frac{P}{A} = I = c\langle u \rangle = c\left(\frac{1}{2}\frac{B_m^2}{\mu_0}\right)$$

$$P = \frac{cB_0^2}{2\mu_0}(4\pi d^2)$$

$$\boxed{P_T = \frac{2\pi c B_0^2 d^2}{\mu_0}}$$

(10) b. Determine the energy absorbed by the antenna in a time Δt.

$$E_T = P\Delta t = IA_A\Delta t = c\langle u \rangle \pi a^2 \Delta t = c\left(\frac{1}{2}\frac{B_0^2}{\mu_0}\right)\pi a^2 \Delta t$$

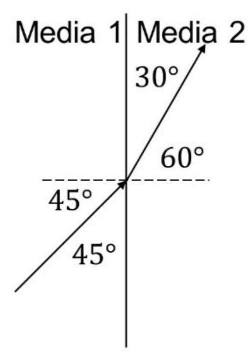
$$\boxed{E_T = \frac{cB_0^2 \pi a^2 \Delta t}{2\mu_0}}$$

(10) c. Determine the magnitude of the force experienced by the antenna.

$$\frac{F}{A_A} = \langle P_{\mathrm{rad}} \rangle = \frac{I}{c} = \langle u \rangle = \frac{1}{2}\frac{B_0^2}{\mu_0}$$

$$\boxed{F = \frac{B_0^2 \pi a^2}{2\mu_0}}$$

10. A beam of light strikes a plane interface between two media, as illustrated.



(10) Determine the index of refraction for media 2 in terms of n_1 the index of refraction for media 1. [Your answer may have a square root.]

$$n_2 \sin\theta_2 = n_1 \sin\theta_1$$

$$n_2 = n_1 \frac{\sin 45°}{\sin 60°} = n_1 \frac{(\sqrt{2}/2)}{(\sqrt{3}/2)}$$

$$\boxed{n_2 = n_1\sqrt{\frac{2}{3}}}$$

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