Official Starting Equations
PHYS 2135, Engineering Physics II

From PHYS 1135:

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

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

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

Constants:

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

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

Electric Force, Field, Potential and Potential Energy:

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

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

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

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

Circuits:

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

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

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

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

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

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:

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

$\vec{F} = I\vec{L} \times \vec{B}$

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

$\oint \vec{B} \cdot d\vec{A} = 0$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enclosed}}$

$\vec{\mu} = NI\vec{A}$

$\vec{\tau} = \vec{\mu} \times \vec{B}$

$U_{\text{dipole}} = -\vec{\mu} \cdot \vec{B}$

$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$

$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2}$

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

$\oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt}$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enclosed}} + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$

$B = \frac{\mu_0 I}{2\pi r}$

$B = \mu_0 n I$

Electromagnetic Waves:

$I = \frac{P}{A}$

$u = \frac{1}{2}\left(\epsilon_0 E^2 + \frac{B^2}{\mu_0}\right) = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$

$\langle u \rangle = \frac{1}{4}\left(\epsilon_0 E_{\max}^2 + \frac{B_{\max}^2}{\mu_0}\right) = \frac{1}{2}\epsilon_0 E_{\max}^2 = \frac{B_{\max}^2}{2\mu_0}$

$\frac{E}{B} = c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$

$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$

$I = \langle S \rangle = c\langle u \rangle$

$\langle P_{\text{rad}} \rangle = \frac{I}{c}$ or $\frac{2I}{c}$

$k = \frac{2\pi}{\lambda}$

$\omega = 2\pi f$

$T = \frac{1}{f}$

$v = f\lambda = \frac{\omega}{k} = \frac{c}{n}$

Optics:

$I = I_{\max} \cos^2 \phi$

$\theta_r = \theta_i$

$n = \frac{c}{v} = \frac{\lambda_0}{\lambda_n}$

$n_r \sin \theta_r = n_i \sin \theta_i$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

$m = \frac{y'}{y} = -\frac{s'}{s}$

$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$f = \frac{R}{2}$

$\frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R}$

$m = \frac{y'}{y} = -\frac{n_a s'}{n_b s}$

$\Delta L = m\lambda$

$\Delta L = \left(m + \frac{1}{2}\right)\lambda$

$\Delta L = d \sin \theta$

$\phi = 2\pi\left(\frac{\Delta L}{\lambda}\right)$

$I = I_0 \cos^2 \frac{\phi}{2}$

$R = \frac{\lambda}{\Delta\lambda} = Nm$

$m\lambda = a \sin \theta$

$\beta = \frac{2\pi}{\lambda} a \sin \theta$

$I = I_0 \left[\frac{\sin(\beta/2)}{\beta/2}\right]^2$

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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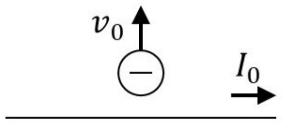
PHYS 2135 Exam III
April 19, 2022

Name: ____________________ Section: _________

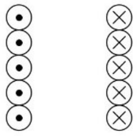
For questions 1-5, select the best answer. For problems 6-9, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed. Use appropriate units. Provide answers in terms of given variable and fundamental constants.

(8) **D** **1.** An electron is initially moving away from a long straight wire that is carrying a current as illustrated. Determine the initial direction of the magnetic force acting on the electron.



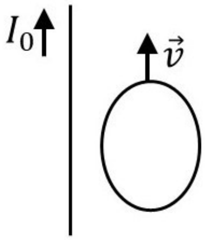
[A]	To the right	[B]	Up	[C]	Out of the page
[D]	To the left	[E]	Down	[F]	Into the page

(8) **2.** The illustration shows a cross-section of a solenoid with the direction of current. Circle the direction of the magnetic field at the center of the solenoid.



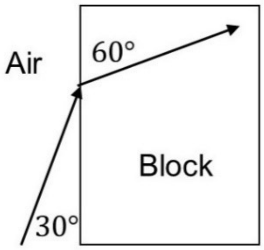
⊙ ⊗ [✓ ↑] ↓ → ←

(8) **A** **3.** A long straight wire carries a current I_0. A conducting loop near the wire is moved with constant velocity $\vec{v}$ as illustrated. The induced current in the loop is …



- [A] Zero
- [B] Down
- [C] Up
- [D] Clockwise
- [E] Counter-Clockwise

(8) **D** **4.** Light originating in air enters a block as shown. Determine n_B the index of refraction of the block.



- [A] $n_B = \frac{1}{\sqrt{3}}$
- [B] $n_B = \frac{\sqrt{2}}{2}$
- [C] $n_B = \frac{\sqrt{3}}{2}$
- [D] $n_B = \sqrt{3}$

(8) **FREE** **5.**

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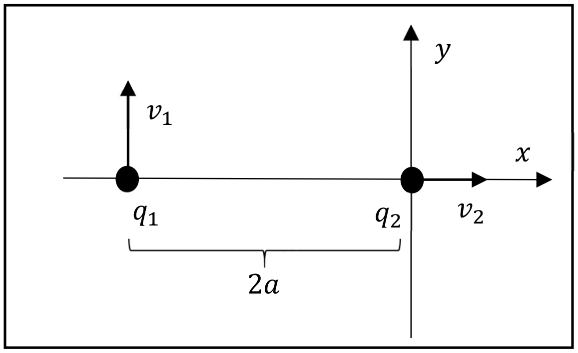

6. A nuclei with positive charge q_1 and velocity $\vec{v}_1 = v_1\hat{j}$ passes through the point (-2a, 0, 0) at a given instant in time just as a charged particle q_2 with velocity $\vec{v}_2 = v_2\hat{\imath}$ passes through the origin (0, 0, 0). z is out of the page.

(10) a. Determine the magnetic field produced by q_1 at the origin at this instant.

$$\vec{B}_1 = \frac{\mu_0}{4\pi}\frac{q_1\vec{v}_1\times\hat{r}_1}{r_1^2}$$

$$\vec{B}_1 = \frac{\mu_0}{4\pi}\frac{q_1v_1(\hat{j}\times\hat{\imath})}{4a^2}$$

$$\boxed{\vec{B}_1 = \frac{\mu_0 q_1 v_1}{16\pi a^2}(-\hat{k})}$$

(10) b. Determine the magnetic field produced by q_2 at the location of q_1 at this instant.

$$\vec{B}_2 = \frac{\mu_0}{4\pi}\frac{q_2\vec{v}_2\times\hat{r}_2}{r_2^2}$$

$$\vec{B}_2 = \frac{\mu_0}{4\pi}\frac{q_2v_2(\hat{\imath}\times-\hat{\imath})}{4a^2}$$

$$\boxed{\vec{B}_2 = 0}$$

(10) c. Determine the magnetic force $q_1$exerts on q_2 at this instant.

$$\vec{F}_{12} = q_2\vec{v}_2\times\vec{B}_1$$

$$\vec{F}_{12} = q_2v_2\hat{\imath}\times\frac{\mu_0q_1v_1}{16\pi a^2}(-\hat{k})$$

$$\boxed{\vec{F}_{12} = \frac{\mu_0 q_1 q_2 v_1 v_2}{16\pi a^2}\hat{j}}$$

(10) d. Determine the magnetic force $q_2$exerts on q_1 at this instant. (Hint: Do not assume it is equal and opposite to the answer to part c.)

$$\vec{F}_{21} = q_1\vec{v}_1\times\vec{B}_2$$

$$\boxed{\vec{F}_{21} = 0}$$

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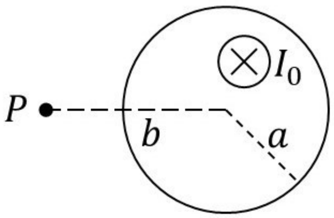
7. An infinitely long straight wire of radius a carries a uniform current I_0 into the page as illustrated.



(15) a. Use Ampere's Law to **derive** the magnitude of the magnetic field at point P, a distance b from the center of the wire.

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{en}$$

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

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

(5) b. Select the direction of the magnetic field at point P.

⊙ ⊗ [✓ ↑] ↓ → ←

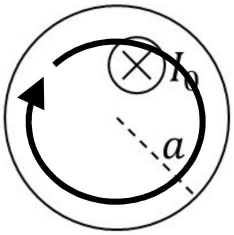
(15) c. Use Ampere's Law to **derive** the magnitude of the magnetic field inside the wire at a distance $r < a$ from the center of the wire.

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

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

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

(5) d. Sketch the magnetic field at a distance $r < a$ from the center of the wire.



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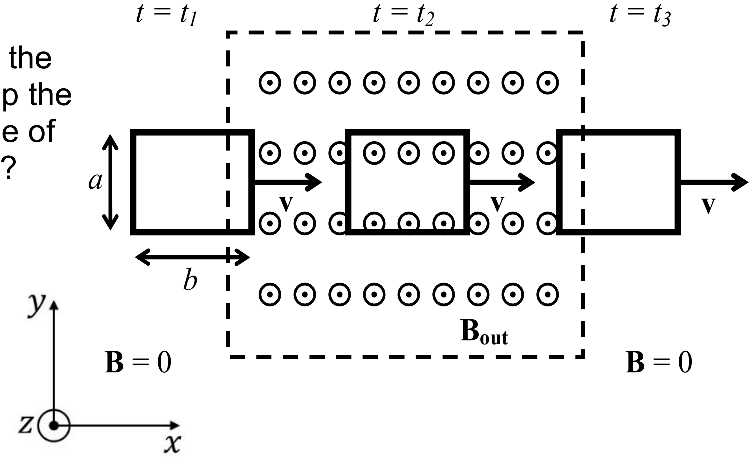
8. A rectangular conducting loop with sides of length *a* and *b* and total resistance *R* is pulled through a region of constant magnetic field **B**

(10) a. At which of the three times is the magnetic flux through the loop the greatest ***and*** what is the value of the magnetic flux at that time?



Max Φ_B at $t = t_2$

$\Phi_B = Bab$

(20) b. What is the magnitude and direction (circle correct direction) of the induced current in the loop at each time? You must justify your answers for the directions of the induced current. Provide answers in terms of given quantities.

At $t = t_1$, $I = \frac{Bav}{R}$
[✓ CW] CCW None Up Down

At $t = t_2$, $I = 0$
CW CCW [✓ None] Up Down

At $t = t_3$, $I = \frac{Bav}{R}$
CW [✓ CCW] None Up Down

$$\Phi_B = Bax$$

$$|\mathcal{E}| = \left|\frac{d\Phi_B}{dt}\right| = Ba\frac{dx}{dt} = Bav$$

$$I = \frac{|\mathcal{E}|}{R}$$

(10) c. What is the magnitude and direction of the magnetic force on the loop at each time? Provide answers in terms of given quantities.

At $t = t_1$, $\vec{F} = \frac{B^2a^2v}{R}$ (←)

At $t = t_2$, $\vec{F} = 0$

At $t = t_3$, $\vec{F} = \frac{B^2a^2v}{R}$ (←)

$$\vec{F} = I\vec{L} \times \vec{B}$$

$$F = IaB$$

$$F = \left(\frac{Bav}{R}\right) aB$$

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9. The James Webb Space Telescope (JWST) observes signals from very early Universe at the L2 point, 1.6 million km away from the earth. JWST sends the signals through a 24GHz frequency channel to NASA's dish antenna with diameter of 32m on the earth. The average total power received at the antenna is 4×10^{-13} watts. $[1\text{GHz} = 1 \times 10^9\text{Hz}]$

(10) a. What is the wavelength of the radiation JWST sends?

$$\lambda = 0.0125\ \text{m}$$

$$\lambda f = c$$

$$\lambda = \frac{c}{f} = \frac{3\times10^8\text{m/s}}{24\times10^9/s}$$

(15) b. Determine the power which JSWT radiates, assuming that the radiation is uniformly transmitted by JWST.

$$P = 16\ \text{kW}$$

$$\frac{P_T}{A_T} = I = \frac{P_{Ant}}{A_{Ant}}$$

$$P_T = \frac{P_{Ant}A_T}{A_{Ant}} = \frac{P_{Ant}\left(4\pi R^2\right)}{\pi(D/2)^2}$$

$$P_T = \frac{\left(4\times10^{-1}\ \text{W}\right)4\pi\left(1.6\times10^9\text{m}\right)^2}{\pi(32\text{m}/2)^2}$$

(15) c. Find the force exerted by the radiation on the antenna when the radiation is absorbed by the antenna. Set the answer for b) as *P*, the distance between the earth and L2 as *R*, and the antenna diameter as *D*. Give a symbolic answer.

$$F = \frac{PD^2}{16cR^2}$$

$$\frac{F}{A_{Ant}} = \langle P_{rad} \rangle = \frac{I}{c}$$

$$F = \frac{IA_{Ant}}{c} = \left(\frac{P_T}{A_T}\right)\left(\frac{A_{An}}{c}\right)$$

$$F = \left(\frac{P_T}{4\pi R^2}\right)\left(\frac{\pi(D/2)^2}{c}\right)$$

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