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:

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

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

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

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

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

Magnetic Force, Field and Inductance:

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

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

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

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

Electromagnetic Waves:

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

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

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

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

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

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

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

Integral:

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

Last updated, June 10, 2021

Exam Total

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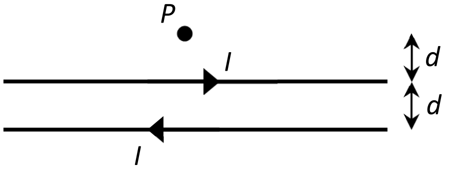
PHYS 2135 Exam III
November 16, 2021

Name: ____________________ Section: _________

For questions 1-5, select the best answer. For problems 6-11, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed.

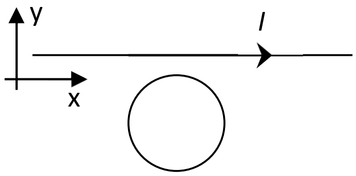
(8)___**B**___**1.** Two long, straight parallel wires carry currents *I* in opposite directions. The wires are a distance *d* apart. What is the direction of the magnetic field at *P*, located *d* above the upper wire?

[A] ⊗ [B] ⊙ [C] ↓ [D] ↑



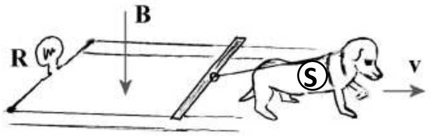
(8)___**B**___**2.** A solenoid has length *L*, *N* turns, carries a current *I*, and produces a magnetic field *B* at its center. Which of the solenoids below would produce the same magnetic field at its center?
[A] a solenoid of length *L*/2, *N* turns, and current 2*I*
[B] a solenoid of length 2*L*, *N* turns, and current 2*I*
[C] a solenoid of length *L*/2, 2*N* turns, and current *I*
[D] a solenoid of length 2*L*, *N*/2 turns, and current *I*.

(8)___**B**___**3.** A loop of wire is positioned next to a long straight wire carrying a current as shown. Which direction must the loop move to generate a clockwise current?
[A] +y [B] –y
[C] +x [D] –x



(8)___**D**___**4.** For an electromagnetic wave, which of the following is true?
[A] The energy is transported in a direction perpendicular to both the electric and magnetic field vectors.
[B] The energy associated with the electric field equals the energy associated with the magnetic field.
[C] At any instant, the ratio of the magnetic to electric field magnitudes is constant.
[D] All of the above.

(8)________**5.** (Free) Muffi the Super Dog wants to generate electricity. What should she do?
[A] Wear a magnetic collar and jump through copper hoops.
[C] See picture below.
[B] Chase a herd of statically charged sheep around a large copper torus.
[D] Two words: tread mill.



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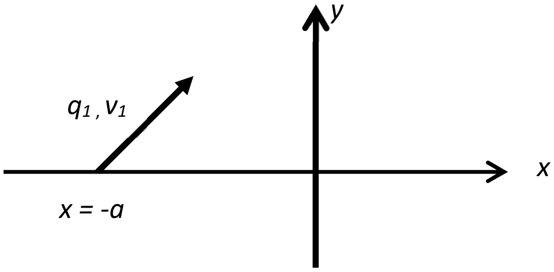
6. At a given instant in time, a negatively charged particle q_1 is crossing the *x*-axis at $x = -a$ with a velocity $\vec{v}_1 = v_x\hat{\imath} + v_y\hat{\jmath}$ as illustrated. Note that both v_x and v_y are positive.



(10) a. What is the direction of the magnetic field produced at the origin?

$\hat{k}$

(20) b. Determine the magnitude, B_0, of the magnetic field produced at the origin by the charged particle, q_1.

$$B_0 = \frac{-\mu_0 q_1 v_y}{4\pi a^2}$$

$$B_0 = \left|\frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}\right|$$

$$B_0 = \left|\frac{\mu_0 q_1 (v_x\hat{\imath} + v_y\hat{\jmath})\times\hat{\imath}}{4\pi a^2}\right|$$

$$B_0 = \left|\frac{\mu_0 q_1 v_y(-\hat{k})}{4\pi a^2}\right| = \left|\frac{\mu_0 q_1 v_y}{4\pi a^2}\right|$$

Note that $q_1 < 0$. Thus, $|q_1| = -q_1$.

(10) c. A loop of wire carries a current in the clockwise direction as illustrated. Determine the direction of the magnetic field at point R.

Into the page.

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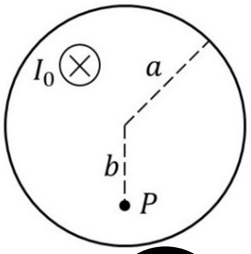
7. A long straight wire of radius a carries a current I_0 into the page as illustrated. The point P is located a distance b below the axis of symmetry of the wire.



(5) a. Determine the direction of the magnetic field at point P. [Circle the correct answer out of the six options.]

⊙ ⊗ ↑ ↓ → [✓ ←]

(15) b. Beginning with Ampere's Law, determine the magnitude of the magnetic field at point P.

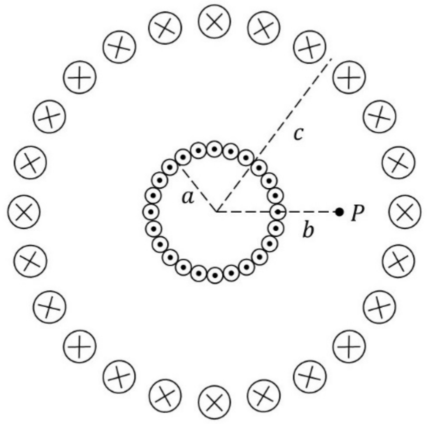
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{enc}$$

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

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

$$\boxed{B_P = \frac{\mu_0 I_0 b}{2\pi a^2}}$$

8. A toroidal solenoid with an inner radius a, and outer radius c consists of N loops and carries a current I_0, as illustrated. The point P is located a distance b to the right of the center of the toroidal solenoid.



(5) a. Determine the direction of the magnetic field at point P. [Circle the correct answer out of the six options.]

⊙ ⊗ [✓ ↑] ↓ → ←

(15) b. Beginning with Ampere's Law, determine the magnitude of the magnetic field at point P.

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

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

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

$$\boxed{B_P = \frac{\mu_0 N I_0}{2\pi b}}$$

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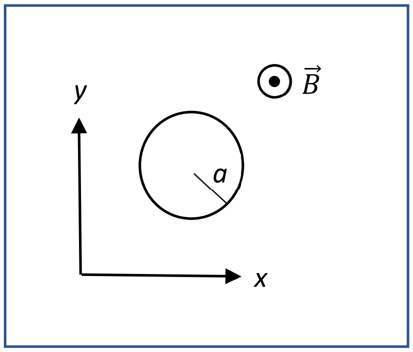
9. A circular wire loop with radius *a* and resistance *R* lies in the *xy*-plane. There is a spatially uniform time-dependent magnetic field in the region $\vec{B} = B_0 b t^2 \hat{k}$, where $B_0 b > 0$.



(10) a. Determine the magnitude of the magnetic flux through the loop of wire as a function of time

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

$$\Phi_B = (B_0 b t^2)(\pi a^2)$$

$$\boxed{\Phi_B = B_0 b \pi a^2 t^2}$$

(10) b. Determine the magnitude of the induced emf in the loop of wire as a function of time

$$\boxed{\mathcal{E} = 2B_0 b \pi a^2 t}$$

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

$$\mathcal{E} = \frac{d}{dt}[B_0 b \pi a^2 t^2]$$

(10) c. Determine the magnitude of the induced current in the loop of wire as a function of time

$$\boxed{I = \frac{2B_0 b \pi a^2 t}{R}}$$

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

(10) d. Determine the direction of the induced current

Clockwise

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10. A source of electromagnetic radiation with power P radiates uniformly in all directions.

(10) a. At a distance D from the source find the maximum value of the magnetic ***and*** electric fields of the electromagnetic radiation.

$$\frac{P}{4\pi D^2} = \frac{P}{A} = I = c\langle u\rangle = \frac{1}{2}c\epsilon_0 E_{\max}^2$$

$$\frac{E}{B} = c$$

$$B = \frac{E}{c} = E\sqrt{\mu_0\epsilon_0} = \frac{1}{D}\sqrt{\frac{P}{2\pi c\epsilon_0}}\sqrt{\mu_0\epsilon_0}$$

$$\boxed{E_{\max} = \frac{1}{D}\sqrt{\frac{P}{2\pi c\epsilon_0}}}$$

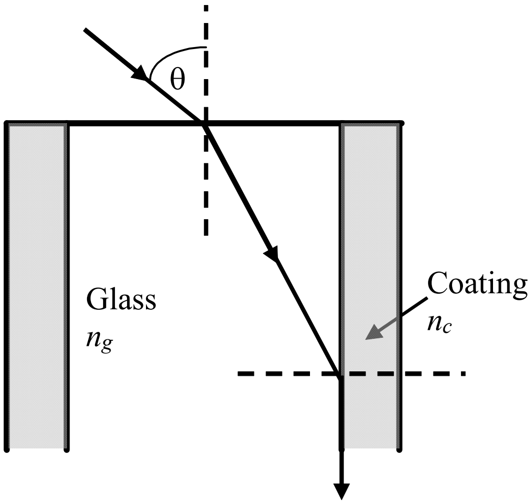
$$\boxed{B_{\max} = \frac{1}{D}\sqrt{\frac{P\mu_0}{2\pi c}}}$$

(10) b. A perfectly reflecting surface is placed a distance D m from the source with its surface perpendicular to the incident radiation. Calculate the radiation pressure on this surface.

$$\langle P_{rad}\rangle = \frac{2I}{c} = \frac{2P}{4\pi D^2 c}$$

$$\boxed{\langle P_{\text{rad}}\rangle = \frac{P}{2\pi D^2 c}}$$

11. An optical fiber consists of a glass core with index of refraction n_g surrounded by a coating with index of refraction n_c. Light enters the end of the cable from the air at an angle θ as shown. The light strikes the surface between the glass and the coating at the critical angle so that the light is refracted along the boundary between the glass and the coating.



(5) a. For the incidence angle at the vertical surface to be the critical angle which must be true? (circle one):

[✓ $n_g > n_c$]

$n_c > n_g$

(15) b. Determine the critical angle.

$$n_g \sin\theta_c = n_c \sin 90°$$

$$\sin\theta_c = \frac{n_c}{n_g}$$

$$\boxed{\theta_c = \sin^{-1}\left(\frac{n_c}{n_g}\right)}$$

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