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:

$g = 9.8\,\frac{\text{m}}{\text{s}^2}$ $m_{\text{electron}} = 9.11\times10^{-31}\text{kg}$ $m_{\text{proton}} = 1.67\times10^{-27}\text{kg}$ $e = 1.6\times10^{-19}\text{C}$

$c = 3.0\times10^8\,\frac{\text{m}}{\text{s}}$ $k = \frac{1}{4\pi\epsilon_0} = 9\times10^9\,\frac{\text{Nm}^2}{\text{C}^2}$ $\epsilon_0 = 8.85\times10^{-12}\,\frac{\text{C}^2}{\text{Nm}^2}$ $\mu_0 = 4\pi\times10^{-7}\,\frac{\text{Tm}}{\text{A}}$

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:

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

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

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

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

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:

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

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

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

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

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

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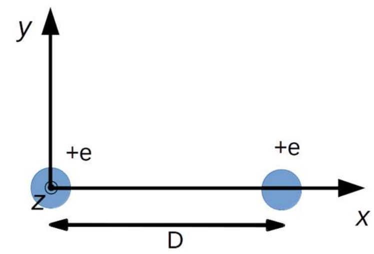
Exam Total
/200

Physics 2135 Final Exam
December 10, 2019

Printed Name: ______________________________

1. Two protons are held fixed at a distance D on the x-axis as illustrated in the figure. The first proton is at $\vec{x}$= *(0, 0, 0)*. The second proton is at $\vec{x}$= *(D, 0, 0)*.



(8) (a) At which point is the electric field $\vec{E}$ zero? Express your answer in vector form using given symbols.

$\vec{x} = (\quad\quad)\hat{\imath} + (\quad\quad)\hat{\jmath} + (\quad\quad)\hat{k}$

(8) (b) Compute the electric potential at $\vec{x}$= *(D/2,0,*0). Express your answer using given symbols.

$V =$

(8) (c) An electron is placed at point $\vec{x}$= *(D/2, 0, 0).* All particles are held fixed. Compute the force on the electron due to the protons. Express your answer in vector form using given symbols.

$\vec{F} =$

(8) (d) Compute the electric potential energy of the electron. Assume the energy is zero at infinity. Express your answer using given symbols.

$U =$

(8) (e) The electron is moved to $\vec{x}$= *(D/2, D/2, 0)* and then it is released (the protons are still held fixed). In which direction the electron will move as soon as it is released? Circle one.

$+\hat{\imath}$ $\quad$ $-\hat{\imath}$ $\quad$ $+\hat{\jmath}$ $\quad$ $-\hat{\jmath}$ $\quad$ $+\hat{k}$ $\quad$ $-\hat{k}$

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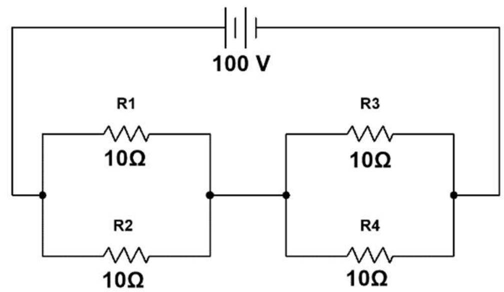
2. Four 10Ω resistors are connected to a $100\ V$ power supply as shown in the figure.

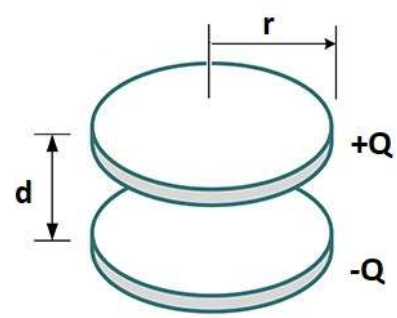


(8) (a) Compute the equivalent resistance for the entire circuit.

(8) (b) Compute the total current coming out of the power supply.

(8) (c) Compute the total power dissipated in the entire circuit.

3. A parallel plate capacitor consists of a pair of circular plates of radius **r** that are separated by a distance **d**. The top plate has a charge **+Q** and the bottom plate a charge **-Q**. Express answers using given symbols and constants.



(8) (a) What is the capacitance of this parallel plate capacitor?

(8) (b) Determine the energy stored in this capacitor.

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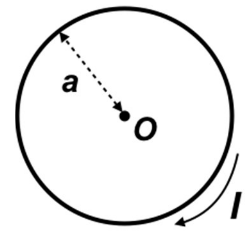
4. A current I runs through a circle with radius of a. You want to find the magnetic field at the center O.



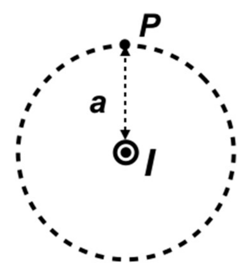
(6) (a) Give the proper OSE for this purpose.

(3) (b) Circle the direction of the magnetic field at the center O.

(i) ⊙ (ii) ↺ (iii) ⊗ (iv) ↻

(6) (c) Find the magnitude of the magnetic field at the center O.

5. A current I runs through an infinitely long straight wire going out of the page. You want to **derive** the magnetic field at P whose distance from the wire is a.



(6) (a) Give the proper OSE for this purpose.

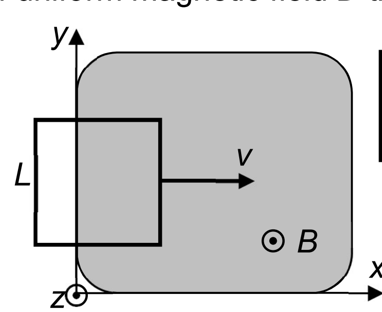
(3) (b) Circle the direction of the magnetic field at P.

(i) ⊙ (ii) → (iii) ⊗ (iv) ←

(6) (c) **Derive** the magnitude of the magnetic field at P.

6. A conducting square loop of N turns with sides of length L is being pulled with steady speed v into a region of uniform magnetic field B that points out of the page.

(10) Find the magnitude of the induced emf ε in the loop.



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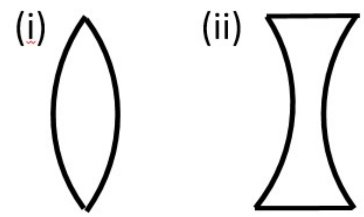
7. A spherical mirror has a radius of $R = 20\text{cm}$. It forms an image of a candle. The image is inverted and 0.5 times as large as the object.

(8) (a) Calculate the image distance *s'*.

(8) (b) The candle is now removed and a new object is placed at position *s'* found from part (a). Find the magnification of the image of the new object.

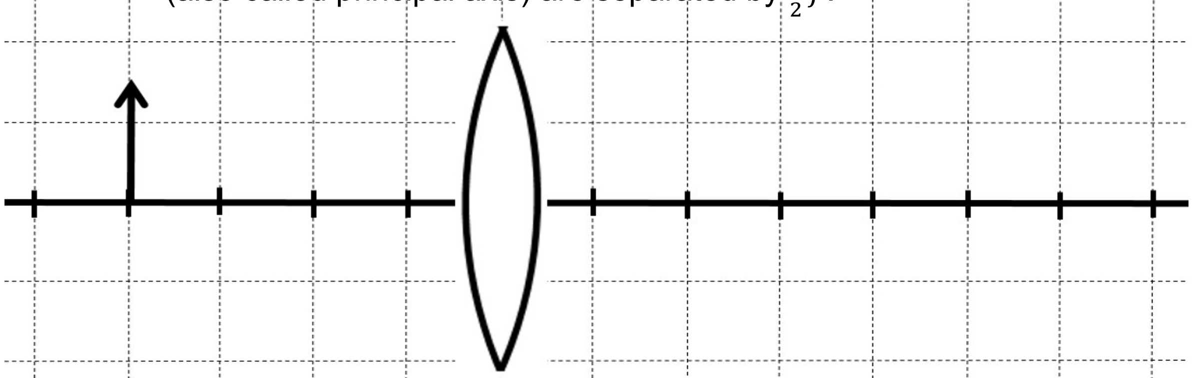
8. Two lenses in the figure on the right are made of a material with an index of refraction of 2 and are surrounded by air. The radii of curvature of the lens surfaces have a magnitude of 20cm.



(8) (a) Calculate the focal length of the lens in figure (i) (note that the sign of the focal length is important).

(8) (b) Calculate the focal length of the lens in figure (ii) (note that the sign of the focal length is important).

(8) (c) A candle is placed $2f$ from the lens (i). Construct a ray diagram using two principal rays to locate the image. Adjacent tic marks on the optical axis (also called principal axis) are separated by $\frac{1}{2}f$.



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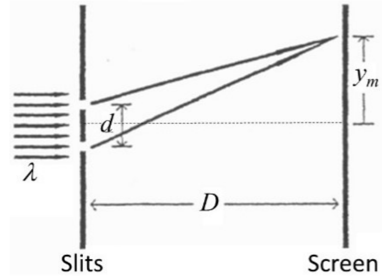
9. A red laser beam with wavelength λ is incident on a two slits, creating an interference pattern of bright and dark fringes. The two slits are separated by a distance of *d*. The interference pattern is observed on a screen perpendicular to the laser beam a distance *D* from the slits. y_m is much smaller than D ($y_m \ll D$). Therefore, use a small angle approximation to get full credit and to avoid excessive work.

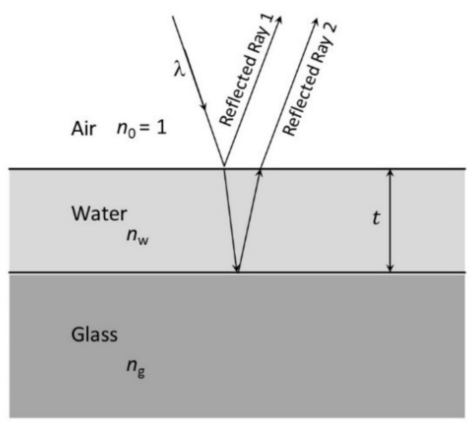


(5) (a) Write an expression for the position y_m of the constructive interference in terms of *λ, d and D.*

(5) (b) Write an expression for the position y_m of the destructive interference in terms of *λ, d and D.*

(10) (c) If the two-slit experiment is now immersed in liquid with index of refraction *n*, find the separation between the <u>first bright fringe</u> away from the central maximum and the <u>second dark fringe</u> away from the central maximum.

10. A laser beam with wavelength λ shines from air down on a thin layer of water (index of refraction n_w) which is placed on top of a glass (index of refraction n_g). The water layer has thickness *t.*



(10) (a) If $n_w < n_g$, which reflected ray(s), if any, has 180° phase change? Circle the correct answer.
[A] Neither
[B] Ray 1, but not Ray 2
[C] Ray 2, but not Ray 1
[D] Both

(10) (b) Write a condition for constructive interference (bright reflection) in terms of the given parameters.

/40