↖ your staple goes up there, alongside the original one

Full name (neatly printed) _____

General Physics 122 – Exam 3 – May 3, 2021

Time started _____ Time ended _____

Place taken _____

PLEASE READ ALL THE INSTRUCTIONS THROUGH FIRST!!!!

- To receive full credit for a problem, your work must convincingly demonstrate that you understand the physics involved behind the problem. That means not only providing the correct answer but showing how you obtained your answer.
- Questions represent a mix of conceptual and quantitative issues. Questions are scored according the rubric on the next page
- You may not consult the textbook, your notes, or any source of information other than the equations below.
- You may choose any continuous, uninterrupted 3-hour period in which to take this exam, and the times you record to document compliance are covered by the BSC Honor Code.
- You may use a calculator provided it is not programmed with course-specific information.
- It is important that your answers be neat and clear. Legible handwriting and clear exposition are required, not optional
- Include raw algebraic equations and identify variables. Include units (m, s, m/s, etc.) in calculations and carry them through.
- Box your final answers to help me locate and identify them quickly
- Use only one side of each page of paper.
- Use your own, lined paper. Nothing written on this exam will be graded.
- Do not use paper ripped from a spiral-bound notebook with jagged edges.
- **Do not write your name on any of the pages other than this cover sheet.**
- Start each answer on a new sheet of paper.
- When finished, place this entire exam atop your responses arranged in sequential order, straighten all the edges neatly, and staple them together before handing them in.
- You must turn in the exam to Dr. Pontius unless other arrangements have been made.
- **I reserve the right to assign additional penalties for violating these instructions.**

Honor code:

Don't Panic!

Reminder: Show all your work. Explain thoroughly and justify everything.

Grading rubric:

Level of demonstrated understanding	Example	Score
Complete	Correct, fully justified reasoning and answer	10
	Correct reasoning; minor computational mistakes or omissions; reasonable answer	9
Partial	Some physics errors or a correct setup but no or incomplete execution; substantial omissions	7
	Major physics errors or partial justification provided even if answer is correct; major omissions	5
Little to none	Little of relevance or no justification provided even if answer is correct	3
	Very little of relevance; moderately interesting B. S.	1
	Blank or just a restatement of the question	0

Data that may or may not be of value to you:

$e = 1.60 \times 10^{-19}$ C

$R_E = 6370$ km

$k_e = 8.99 \times 10^{9}$ N·m^2/C^2

$G = 6.673 \times 10^{11}$ N·m^2/kg^2

$\mu_o = 4\pi \times 10^{-7}$ T· m/A

$\varepsilon_o = 8.85 \times 10^{-12}$ C^2/N·m^2

$\mu T = 10^{-6}$T

$nT = 10^{-9}$T

$m_p = 1.67 \times 10^{-27}$ kg

$m_e = 9.11 \times 10^{-31}$ kg

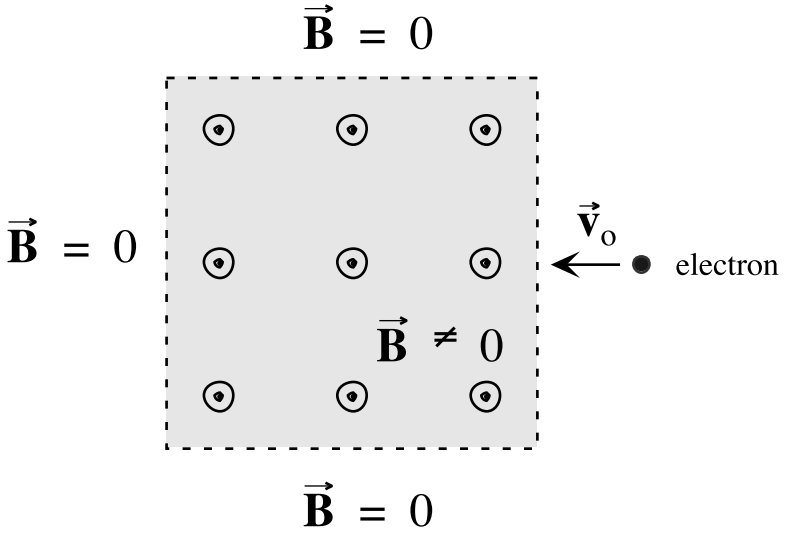
$n_{water} = 1.33$

$n_{glass} = 1.50$

1. An electron is moving horizontally as shown below. It enters the square shaded region within which the magnetic field is uniform and directed out of the page, as shown in the figure below. Everywhere outside of that region, the magnetic field is zero.

a. Reproduce the square boundary on your own paper, and sketch the path of the electron through the region. Include points before it enters the square, within the square, and after it has exited. At each of several points along its path, draw a vector to indicate the magnetic force. The length of each vector should be proportional to the magnitude of the force at that point (i.e., a longer arrow indicates a stronger force), and the notations $F_B = 0$ should appear if the force is zero at that point. If the particle exits the magnetic field region, continue drawing the trajectory for a short segment outside the square, far enough to see the shape of the path it follows. Explain all steps of your reasoning.

b. Now that the electron has departed for distant regions, a proton is given the same initial starting position and velocity, and the magnetic field is unchanged. Repeat the above exercise in a new square drawn to the same scale (vectors too!). Once again, be sure to explain all your reasoning.



2. An electric dipole consists of two equal and opposite charges of magnitude Q separated by a separation vector $\vec{\mathbf{d}}$. The electric field $\vec{\mathbf{E}}$ from a dipole at a position $\vec{\mathbf{r}}$ displaced from their center is given by the following formula, where the angle θ is measured from the direction of the separation vector. For the following questions, explain your reasoning clearly and be sure to show that the units in your answers are correct.

$$\vec{\mathbf{E}}(\vec{\mathbf{r}}) = \frac{Qd}{4\pi\epsilon_o}\frac{\left(3\,\hat{\mathbf{r}}\cos\theta - \hat{\mathbf{d}}\right)}{r^3}$$

a. For $Q = 10^{-6}\text{C}, d = 10^{-10}\text{m}$, determine the net electric flux through a gaussian sphere centered on the dipole with radius $R = 10^{-4}\text{m}$.
b. Answer the same question if a third charge of magnitude Q is placed between the two original charges of the dipole.

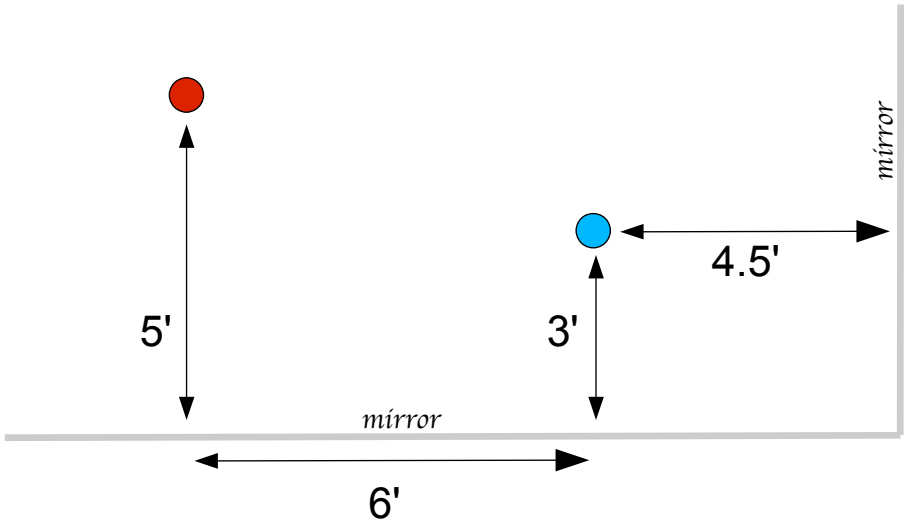
3. A pair of infinite, horizontal line currents run parallel to each other, separated by a vertical distance D. Each wire carries a current of magnitude I to the right. Explain in words each of the following two situations before presenting any mathematical calculations.

a. Exactly midway between the two wires, an electron is initially moving at speed v in the same direction as the current. Find the force (magnitude and direction) exerted on the electron in terms of the algebraic parameters given and any fundamental constants needed.
b. Repeat for a second electron with the same initial velocity but located a distance D/3 above the lower wire. (Do not include any forces between the two electrons.)

4. You are aboard the Nautilus, a classic science fiction era submarine, submerged under the crystal clear waters of the Caribbean Sea. Using an ordinary camera, you adjust the lens so that it focuses on the proud Captain Nemo (no relation to the fish of the same name) standing 2.7 meters away on the ship's bridge with you. Suddenly, out of the corner of your eye, you spot what looks like a mermaid through the flat glass of the porthole next to you. (The glass is very strong but negligibly thick). Taking no time to adjust the camera, you turn, aim it directly through the window, and snap a picture, which by amazingly good fortune happens to produce a perfectly focused picture of…a rather shabby looking scuba diver. If you were standing 0.56 meters from the porthole, how far away from you on the other side was the diver? Explain your reasoning. Hint: draw figures showing ray paths.

5. Okay, a boring traditional question. An object 2.0 cm high is placed 1.0 m to the left of a **diverging** lens. One meter to the right of that lens is another lens, which is **converging**. The magnitude of the focal length for each individual lens is 1.0 m. Draw ray diagram(s) showing all three principal rays for both lenses. Then find the intermediate and final images algebraically and specify their location, size, and other characteristics. Interpret the algebraic signs of all values, both those that you assign and those that arise from calculations.

6. The walls in ballet studios are always hung with full-length mirrors. A pair of dancers in red and blue leotards stand facing the mirror at the bottom of the figure. (In case they don't teach it in grade school anymore, 5' = 5 feet, and so forth.)



a. How far away from the red dancer–the observer–is the image of the blue dancer–the object–in the mirror at the bottom of the figure? Explain your logic.

b. There's obviously a second image of the blue dancer in the mirror on the right side, but ignore that one. The red dancer sees a third image between the other two, in the lower right of the figure. Starting with the blue dancer as the primary object, describe and explain the sequence of reflections that produces that third image and calculate how far it is from the red dancer.