Name: _____

PH122 – Exam 3 –2018

Time Started _____ Time Ended _____ Place Taken _____

Instructions and Notes – You will lose points if you do not comply.

- You are only allowed three hours (or a pre-arranged accommodation) to take this exam. Pay careful attention to time! If you go over time, I will deduct points in proportion to how much time you go over the allotted amount.
- You are allowed one 8.5 inch by 11 inch piece of paper, with whatever information you choose to include on the front and back, as your only source of information outside of this exam paper. You may not consult your textbook, notes, or any other source of information.
- You are allowed to use a scientific calculator, but it must not be programmed with course-specific information. You may not use a cell phone as a calculator, but you can use it as a clock. (Keep it silent!)
- Unless you have made other arrangements, you will take the exam in one of the general physics laboratories (SSC111 or SSC115).
- Answer all questions on your own loose-leaf paper (not torn out of a spiral notebook).
- You may use only the front side of each sheet to answer the questions. If your answer goes longer than one page, continue on the front of a new sheet of paper and indicate that it is a continuation of that question's answer.
- Answers to each question (not each question part) must start on a new sheet of paper.
- Your answers should be clear, well explained, and legible. It is your job, not mine, to ensure that I understand your answer. If you have a muddled answer and time remains at the end of the test, re-write it neatly on a new sheet of paper and submit the clear answer.
- Box final answers to calculation/symbolic questions so I can easily locate your answer.
- The grading rubric is listed on the back of this page. You must demonstrate that you understand the physics involved in the problem in order to receive full credit. A correct answer is not sufficient. You must show how you obtained that answer.
- Show enough detail in algebraic manipulations to ensure I can follow your work.
- Include units in all calculations and include them through all steps of a calculation. I will deduct points for correct solutions for which you do not include units with numerical values through every step of the solution!!!
- When you finish the exam, arrange all answer sheets in order and staple them together with these exam sheets on top.

Sign That You Have Upheld
The Honor Code During This Exam: _____

Grading Rubric

Each problem will be graded on a 10-point scale. The table below shows examples of how I will assign points.

<u>High Level of Understanding Demonstrated</u>

10 points:	correct answer and explanation
9 points:	correct reasoning with a reasonable answer but minor computational errors

<u>Partial Understanding Demonstrated</u>

7 points:	physics errors (or correct setup but incomplete execution)
5 points:	major physics errors (or partial justification provided even if answer is correct)

<u>Little to No Understanding Demonstrated</u>

3 points:	little relevant work (or no justification provided even if the answer is correct)
1 point:	very little relevant work
0 points:	no relevant work, recopy of the problem statement with no additional work

Constants

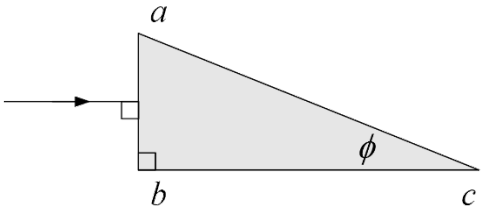
$k_e = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$ $\quad \epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N} \cdot \text{m}^2$ $\quad e = 1.6 \times 10^{-19}\ \text{C}$

$m_e = 9.11 \times 10^{-31}\ \text{kg}$ $\quad m_p = 1.67 \times 10^{-27}\ \text{kg}$ $\quad g = 9.8\ \text{N/kg}$

$\mu_0 = 4\pi \times 10^{-7}\ \text{T·m/A}$ $\quad n_{\text{water}} = 1.33$ $\quad n_{\text{glass}} = 1.5$

Questions

1. You are assigned the task of designing a prism made of a new type of low index glass, "unobtainium" ($n = 1.15$). The design requires that a ray of light initially perpendicular to face ab of the prism should be totally internally reflected at face ac.

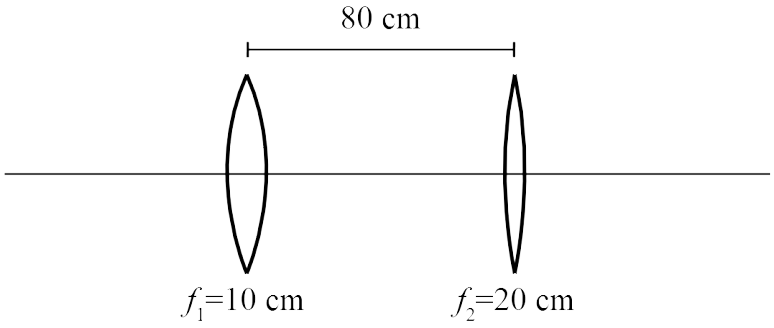


   (a) What minimum angle ϕ will guarantee this total internal reflection when the prism is surrounded by air?

   (b) Based on your answer to part (a), will a ray incident normal to face bc also be totally reflected at face ac? Justify your answer mathematically and or with careful explanation.

   (c) Your boss wants to sell your prisms to the Navy for use in underwater applications. Redo your analysis in part (a) and discuss the implications of this choice.

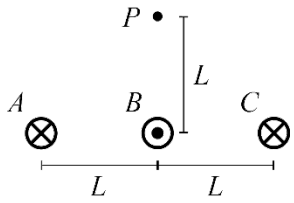
2. A compound lens consists of two thin converging lenses, of focal lengths 10 cm and 20 cm, respectively, and separated by a distance of 80 cm.



(a) Find the location and height of the final image of a 5 cm tall object placed 15 cm to the left of the 10 cm lens. Describe the image carefully. You may sketch ray diagrams on your answer sheet, but ray tracing is not the point of this question. *Do not use the grid at the end of this exam for ray diagrams.*

(b) Repeat the calculation above with the lenses swapped but everything else the same.

3. The figure on the right shows a cross section of three long parallel wires (labeled *A* through *C*) taken in a plane perpendicular to the wires. One or more of the wires may be carrying a current. If a wire carries a current, its magnitude will be I_0 and its direction will be as indicated in the figure.



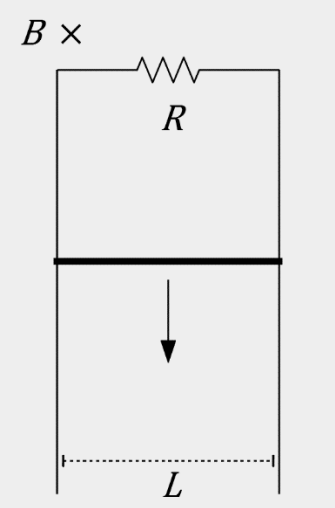
For each of the question parts below, *draw only the relevant wires, points and/or charges*, including the currents as indicated, then *draw and describe the direction of the specified vector quantity*. Take *up* to be "north," *right* to be "east," etc. For example, a vector pointing down would point "south," while a vector pointing equally up and to the left would point "northwest." If the magnitude of the quantity is zero, write "0". As usual, justify all answers by explaining your logic.

(a) The magnetic field at point *P* if only wire *A* is carrying a current.
(b) The magnetic field at wire *C* if only wire *A* is carrying a current.
(c) The magnetic force on wire *C* if only wire *A* is carrying a current.
(d) The magnetic force on wire *C* if all three wires are carrying currents.
(e) The magnetic force on a proton moving to the right at point *P* if all three wires are carrying currents.

4. When I get a speck of debris in my eye, I grab a special handheld mirror to investigate. To ensure I see the speck clearly, the mirror will produce an upright, magnified image when I hold it close to my eye. What kind of mirror (converging/diverging) is this? Prove your answer with lens equations and give an example ray diagram *using the graph paper at the end of this exam.* Make sure to detach that paper and include it in order with your answers. (I have included two pages in case you make a mistake on the first one.) Next, prove with lens equations that my mirror *will not* produce an upright, reduced image.

5. Discuss each of the following. If the situation is possible, draw and/or describe an example. If it is not possible, explain why not.
   (a) Is it possible for a charged particle to move through a magnetic field (with no electric field) without experiencing a force?
   (b) Is it possible for a charged particle to be at rest in the simultaneous presence of a magnetic and an electric field?
   (c) Is it possible for a charged particle to move through non-zero magnetic and an electric fields without experiencing a net force?
   (d) Is it possible for a magnetic dipole to feel a net force in a uniform magnetic field?
   (e) Is it possible for a magnetic dipole to feel no net torque in a uniform magnetic field?

6. A circuit consists of two vertical wires, connected at the top by a fixed resistance R, as shown in the diagram on the right. The resistance of all other wires in the circuit is negligible. The two vertical wires are also connected by a massive conducting rod (thick horizontal line), of mass m and length L, which is free to slide without friction along the vertical wires, maintaining electrical contact with them at all times. (As you see, the rod makes a complete rectangular circuit with fixed width L and variable height.) The entire circuit is in the presence of a uniform magnetic field $\vec{\boldsymbol{B}}$ (gray region) which points into the page, as shown. The rod is released from rest and allowed to slide down the vertical wires under the influence of gravity. Is there an induced current in the circuit? If so, what is its direction (clockwise or counterclockwise)? Is there a magnetic force on the falling rod? If so, what is its direction? Justify your answers by a careful chain of logic expressed in words, formulas when necessary, right-hand rules, etc.



Extra Credit: (do not attempt until you have completed the rest of the exam)
Determine the *terminal speed* of the falling rod, in terms of m, R, L, B, and g.