PH122 — Exam 3 — Spring, 2020

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

- You are only allowed six hours (or a pre-arranged accommodation) to take this exam. This will be plenty of time to work the exam, so you can take the occasional break if you neet.
- 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.
- Answer all questions neatly on your own paper.
- If your answer goes longer than one page, continue on 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.
- Because you will scan and submit all answers electronically, you should ensure that your answers are written with text large enough and dark enough to show up clearly on a scan. Re-write answers in pen if necessary.
- 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. Each page should indicate the question number worked on that page. Using OfficeLens (available for all portable devices) or other scanning app, photograph each page of your exam and save all pages in a single PDF (Adobe Acrobat) file. Upload your PDF file to the designated repository on the course Moodle page.
- Do not turn in this exam paper or your formula sheet with the exam. Your file should contain only your answers.

Grading Rubric

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

High Level of Understanding Demonstrated

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

Partial Understanding Demonstrated

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

Little to No Understanding Demonstrated

- 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 and Unit Conversions

$R = 8.314$ J/mol·K   1 atm = 101 325 Pa $1\ \text{m}^3 = 1000\ \text{L}$ $g = 9.8$ N/kg

$N_A = 6.02 \times 10^{23}$ $k_B = 1.38 \times 10^{-23}$ J/K $k_e = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$

$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N} \cdot \text{m}^2$ $m_{\text{proton}} = 1.67 \times 10^{-27}$ kg $m_{\text{electron}} = 9.11 \times 10^{-31}$ kg $e = 1.6 \times 10^{-19}$ C

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

Thermal Properties of Materials

	Linear Expansion: α (K^{-1})	Specific Heat: c (J/kg·K)
Aluminum	24×10^{-6}	910
Lead	29×10^{-6}	128
Copper	17×10^{-6}	390
Concrete	12×10^{-6}	387
Iron	11×10^{-6}	448
Steel	13×10^{-6}	500
Mercury	61×10^{-6}	140
Glass	3×10^{-6}	840
Water	---	4186
Ice	---	2050

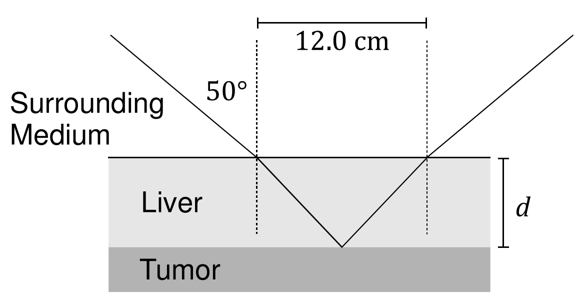
Latent Heats	Fusion: L_f (J/kg)	Vaporization: L_v (J/kg)
Water	3.34×10^5	2.26×10^6
Oxygen	2.55×10^4	2.13×10^5
Aluminum	3.7×10^5	1.14×10^7
Copper	1.34×10^5	5.07×10^6

1. A 5 cm tall candle sits at a distance of 150 cm to the left of a converging lens with a focal length of 50 cm. At a point 50 cm to the right of this lens is a flat mirror. Using both lens/mirror equations and ray diagrams, find the resulting location(s) of the image(s) of the candle. Where would an observer have to be, and in what direction would the observer have to look, to observe the final image(s)? Be specific about each location (e.g., "xxx cm to the left/right of yyy"). Also compute the image height, whether it is real or virtual, and whether it is upright or inverted for each resulting image. This problem is easy to get lost in, so make sure you draw multiple clear diagrams showing, object, lens or mirror, and image for each step in the process! Make sure to explain what you're doing as you work your way through the process. For ray diagrams you may use one or more copies of the "graph paper" image on the last page of this exam, use your own graph paper, or *neatly* draw ray diagrams on plain paper. Rulers really help!

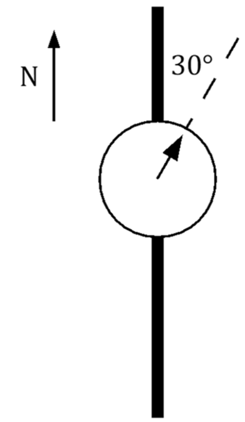
2. What kind of lens (converging or diverging) is used to make a simple magnifying glass? You probably know the answer, but that's no fun – you need to do some work. As you can see from the upper image on the right (from a scene from the movie "The Adventures of Tintin") a magnifying glass is used to make upright, enlarged images of objects. To answer this question, you must first characterize the image as real or virtual. (The object, of course, is real.) Justify your answer using lens equations. Once you have done so, use thin equations to prove that *only one* kind of lens can make such an image for a real object. What kind of lens is it?

   Now consider the lower image on the right, taken from another scene from the movie. Repeat your work from above for this image and prove that *only one* kind of lens can make such an image for a real object. What kind of lens is it? Could this be the same lens as in the previous scene?

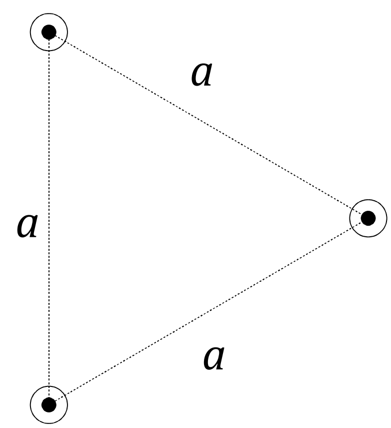
3. A narrow beam of ultrasonic waves reflects off a tumor in the liver as in the diagram below. (For refraction and reflection purposes, treat the sound waves exactly as you would light waves. However, they travel at the speed of sound, not the speed of light.) The speed of sound waves in the liver is 90% of the speed of sound waves in the surrounding medium. The reflected wave returns to the surrounding medium 12 cm from where it enters the liver. Compute d, the depth of the tumor inside the liver, in centimeters



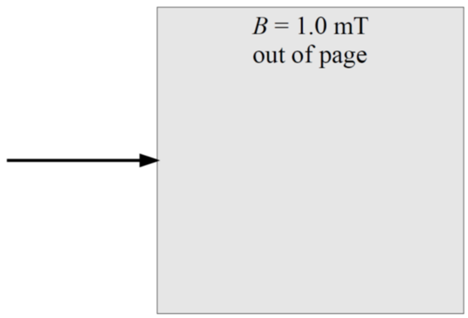
4. A long wire is oriented in the north/south *magnetic* direction as shown in the diagram on the right. A compass is held 10 cm *directly above* the wire. When the wire carries a current I_0, the compass needle makes a 30° angle from magnetic north. The magnitude of Earth's magnetic field is 2×10^{-5} T. Based on the deflection of the compass needle, determine the current, I_0, and whether the direction of the current is directed toward the north or toward the south. Explain your process, including anything you may have done with your right hand to determine the answer.



5. Three long wires are arranged in an *equilateral triangle* of side length a and carry identical currents, I, directed out of the page as shown in the diagram on the right. Determine an expression for the the magnetic field, magnitude and direction, at the location of the wire on the right. Provide clear diagrams and careful explanations to justify your answer. Once you have found the field, determine the force per unit length ($\vec{F}/L$), on the right-hand wire, including magnitude and direction. Again, justify your answer with clear diagrams and careful explanation. Your expressions for $\vec{B}$ and $\vec{F}/L$ should be *algebraic*. I don't want you sticking in arbitrary numerical values for a or I, and I sure don't want you to write out the value of μ_0 in SI units! Remember, correct determination of directions (with justification) is important, even if you mess up the algebra.



6. A beam of protons moving to the right with speed $v = 20\,000$ m/s enters a 1 m × 1 m square region of uniform magnetic field, $B = 1.0 \times 10^{-3}$ T pointing out of the page, as shown in the diagram on the right.



   (a) On your paper, draw the resulting trajectory of the protons, and determine at what position they will leave the magnetic region. Explain your process, including any right-hand rules you might use (diagrams help).

   (b) Repeat the above calculation for electrons with the same initial *kinetic energy* as the protons. Again, explain your process carefully.