PH122 — Exam 2 — 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.

<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 and Unit Conversions

$R = 8.314$ J/mol·K = 0.08206 L·atm/mol·K   1 atm = 101 325 Pa $k_B = 1.38 \times 10^{-23}$ J/K

$N_A = 6.02 \times 10^{23}$ 1 kcal = 4184 J   1 m^3 = 1000 L $k_e = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N·m^2/C^2

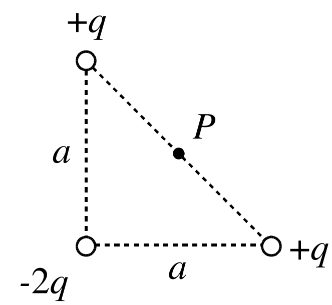
$\varepsilon_0 = 8.99 \times 10^9$ C^2/N·m^2 $m_p = 1.67 \times 10^{-27}$ kg $m_p = 9.11 \times 10^{-31}$ kg $e = 1.6 \times 10^{-19}$ C

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

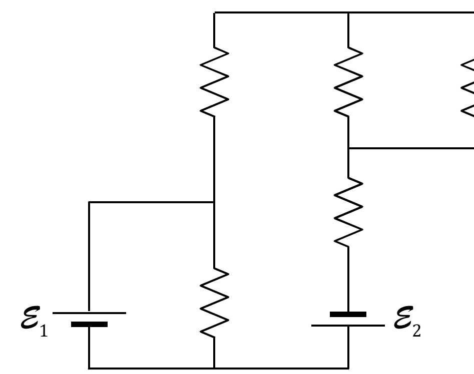
1. Three charges are arranged at the corners of an isosceles right triangle of side length a as shown in the diagram on the right.



   (a) Determine the electric potential at the point P, located halfway between the two charges $+q$.
   (b) Determine the electric field (in component form as well as the magnitude) at point P.
   (c) Determine the total potential energy of the collection of charges.
   (d) Determine the electric force (in component form as well as the magnitude) on the charge $-2q$.

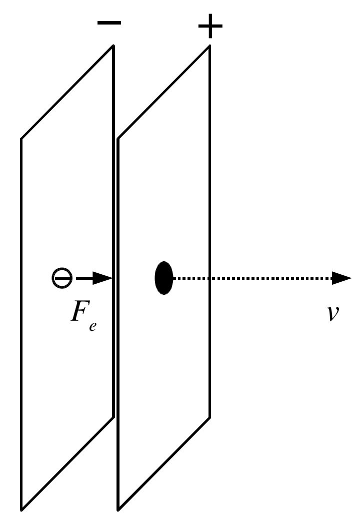
   Explain your work as you go through each step.

2. In the figure on the right, each resistance is 4.00 Ω, while the battery voltages are $\mathcal{E}_1 = 4.00$ V and $\mathcal{E}_2 = 12.00$ V. Reproduce this figure on your paper, label and compute the current through each resistor and battery. Compute also the power dissipated by each resistor and the power delivered to the circuit by each battery.



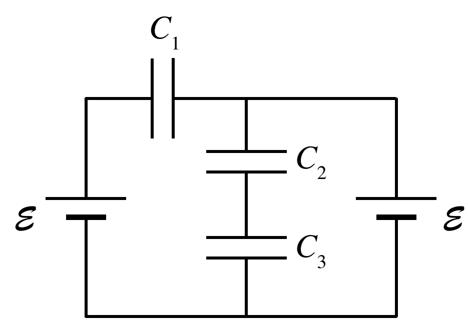
   Explain your work as you go through each step.

3. An "electron gun" such as you might find in an old-fashioned television, accelerates electrons through a potential difference. A simple model of such a device consists of two parallel paltes that are spaced closely together with a potential difference $\Delta V = 2000$ V between them. An electron (charge $q = -1.6 \times 10^{-19}$ C, mass $m = 9.11 \times 10^{-31}$ kg) near the negatively charged plate experiences an electrical force that accelerates it toward the positively charged plate. The electrons pass through a small hole in the positive plate and into a region of no electric field (right of the positive plate). The hole in the positive plate is small enough that is presence does not affect the uniform field between the plates. Compute the speed of the electron in the field-free region to the right of the positive plate. Make sure to explain every step of your procedure.



4. I have an electric smoker at home for times I want to make barbecue without tending a charcoal fire all day. The heating element and its built-in power cord dissipate a total of 1500 W of power when plugged into a 120 V household outlet. (The overwhelming majority of that power is dissipated by the heating element.) **Note:** for the rest of this question, I will refer to the heating element and its built-in power cord collectively as *the smoker*. Unfortunately, I can't use the smoker on my patio without connecting the smoker to the outlet using an extension cord. Electrical cords, of course, are not perfect conductors. I happen to have a 20 foot-long extension cord of #14 gauge width. Doing some research on the internet, I discovered that a #14 gauge extension cord has resistance of 0.60 Ω per 100 foot length. If I connect the smoker *in series* with my extension cord (that's how extension cords work) and a 120 V outlet, what power can I expect to be dissipated by the smoker?

5. Three *identical* capacitors ($C_1 = C_2 = C_3 = C$) are connected to two *identical* ideal batteries as shown on the right. The capacitors are allowed to fully charge in this arrangement.



   (a) Compute the potential difference across each capacitor, the charge stored in each capacitor, and the energy stored in each capacitor. Of course you're going to have to explain and justify what you are doing.

   (b) Leaving the capacitors connected to the batteries, suppose that the plates of C_3 are pushed together, reducing the plate separation to *half* of what it was in part (a), leaving the other two capacitors unchanged. Explain how each quantity (charge, potential difference, and energy) should change or stay the same for each, justifying your answer.

   All answers above should be in terms of C and $\mathcal{E}$.

6. In the circuit on the right, determine the current through each resistor, through the battery, and through the horizontal wire in the middle of the collection of resistors in terms of $\mathcal{E}$ and R. Copy this diagram onto your paper. If you use loops and junctions, clearly label them and make sure I can follow how you got the equations from each. If you reduce combinations of resistors to equivalent resistances, draw new diagrams with clearly labeled equivalent resistances. In any case, make sure I can follow your work to the answer.