PHYSICS 7B – Spring 2020 - Final Exam
Lecture 2, F. Wang
Monday, May 11, 2020
11:30 am-2:30 pm PDT

Make sure you show all your work and justify your answers in order to get full credit!

Honor code

Please read the following honor code and follow the instructions below.

This Honor Code is an undertaking of the student:
• that they will not give, receive, or seek to obtain unpermitted aid or resources during this examination.
• that they will do their share and take an active part in seeing to it that others as well as themselves uphold the spirit and letter of this Honor Code.
The instructors on their part manifest their confidence in the honor of their students by refraining from taking unusual and unreasonable precautions to prevent the forms of dishonesty mentioned above.

To indicate your agreement to abide by the honor code above, please write on the front page:
"I agree to abide by the Honor Code", followed by a signature and date.

A submission without an agreement to abide by the Honor Code may not be graded.

We are also asking you to follow these guidelines:

- Begin part (a) of each problem on a new page, and maintain the page breaks when uploading your solutions (that is, one page (or less) per photo).

- Indicate on Gradescope which page contains your work for each sub-part of each problem.

- Rotate each page so that it is right side up. If you upload a PDF, you can do the rotation of each page in Gradescope. If you upload images, you should make sure they are correctly rotated before uploading.

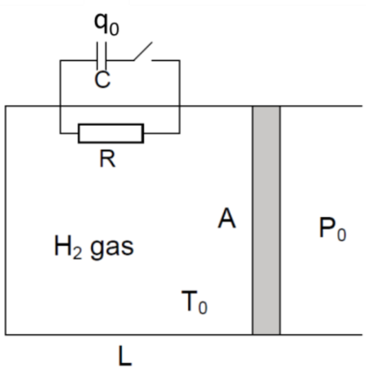
We will apply small deductions (a couple points per problem) for exams that do not meet these requirements.

1. (50 points) A vessel is filled with hydrogen gas (H_2) in a volume with length *L* and cross-section area of *A*. The hydrogen gas is initially near room temperature at T_0 and outside pressure is P_0. A frictionless piston can move in the vessel. A resistor with resistance *R* is in the gas vessel, and it is part of a circuit with a capacitor *C*. The capacitor is charged with q_0.

(a) After we close the switch, calculate the charge on the capacitor as a function of the time.

(b) Calculate the current and power dissipation in the circuit as a function of time.

(c) The heat released by Joule heating will heat up the hydrogen gas. What is the final temperature and volume of the hydrogen gas after the system reaches thermal equilibrium? Neglect the volume and heat capacity of the resistor and assume the gas vessel is thermally well-insulated.

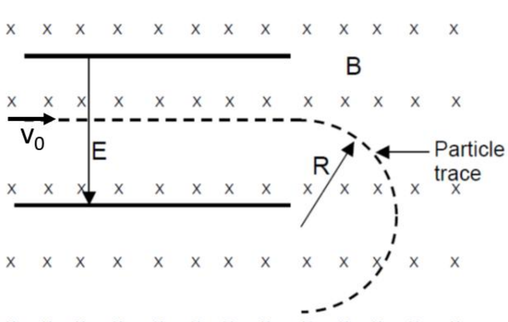


2. (25 points) Examination of the motion of a charged particle in electrical and magnetic field can yield its charge-to-mass ratio, and it has played a crucial role in identifying new particles in the early last century. In the experiment shown in the figure below, the electrical field with strength *E* points down and the magnetic field with strength *B* points into the plane. A charged particle has a trace characterized by a straight line followed by a circular motion with radius *R*.

(a) Is the particle positively or negatively charged?

(b) Determine the initial speed v_0 of the charged particle.

(c) Determine the charge-to-mass ratio *q/m* of the particle.



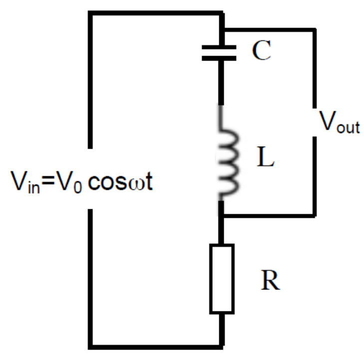
3. (40 points) Resonant RLC circuits can be used to reduce electrical signals at a specific frequency. We will examine this behavior in a circuit described by the following figure. For a given input $V_{in} = V_{in,0} \cos \omega t$, we expect to obtain an output voltage $V_{out} = V_{out,0} \cos \omega t$

(a) Determine the ratio of the output and input voltage amplitude $V_{out,0}/V_{in,0}$ as a function of frequency $f = \omega/2\pi$ for given R, C, and L. Plot out the function qualitatively.

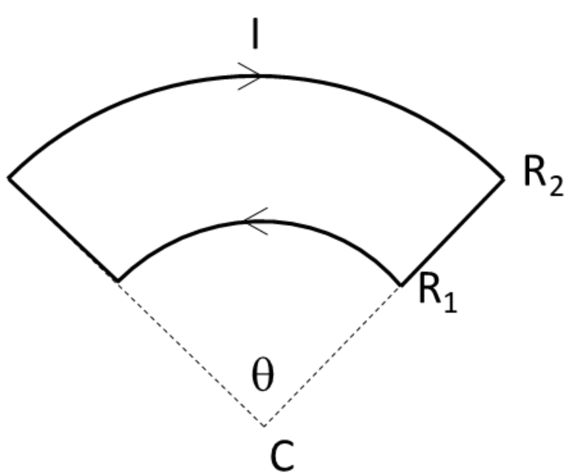
Now we want to design a so called "notch filter" that blocks line frequency noise at 60 Hz and has a bandwidth of 5 Hz. We already have an inductor of 0.1 Henry.

(b) The notch filter will filter out the input signal at 60 Hz, i.e. the circuit will have $V_{out,0}/ V_{in,0} = 0$ at 60 Hz. What value of C do we need to use?

(c) To have a bandwidth of 5 Hz, we require $V_{out,0}/ V_{in,0} = 0.5$ at 65 Hz. What value of R do we need to use for our circuit?



4. (25 points) A wire in a plane has the shape shown below. Two arcs of a wire circle are connected by wire radial segments. Determine the magnetic field strength B at point C in terms of the radii R_1, R_2, and a current I running through the wire.

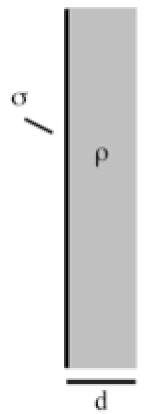


5. (30 points) A very large, thin plane has a uniform surface charge density σ. To the right of this thin plane is a slab of thickness d with a uniform charge density ρ. Set $x = 0$ at the slab center.

(a) Calculate the electric field to the left of the thin plane.

(b) Calculate the electric field to the right of the thick slab.

(c) Calculate the electric field everywhere inside the slab.



6. (30 points) A conducting rod of length L rotates at a constant angular velocity ω around one end, in a plane perpendicular to a uniform magnetic field B.

(a) Calculate the magnetic force on a charge q at a distance r from the pivot.

(b) Calculate the induced electrical potential difference between the ends of the rod.