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# Final Exam, Physics 1B, Winter 2020

Section 1 – Thomas Dumitrescu

• If you are writing directly on this exam, please write your name and UID in the boxes on the front page and your name in the boxes at the top of the odd numbered pages. Please write your answers within the margins outlined by the boxes on each page. If you are using the "additional space" pages, please label them carefully and refer to them within the answer box for the original problem.

• If you are writing your exam on note paper, please write the page number, as well as your name and UID at the top of every page. Indicate clearly which problem you are working on.

• The exam is open book: you can use the textbook and all the material posted on the class website (including CCLE, Kudu, and the homework on Mastering Physics). Googling answers is not allowed, and also not helpful.

• Calculators are allowed, but computer algebra systems (such as Mathematica or Maple) are not.

• Questions during the exam can be posted on Questionsly or sent to me by email. Major clarifications will be emailed to all students via our myUCLA class email.

• **The exam is 90 minutes long. You have until 4:30pm PST on Monday, March 16 to upload your answers to Gradescope as a a single pdf**.

• There are 4 questions; the exam has 13 pages.

## Good Luck !!

-additional space for calculation- Please denote exactly which problem you are working on

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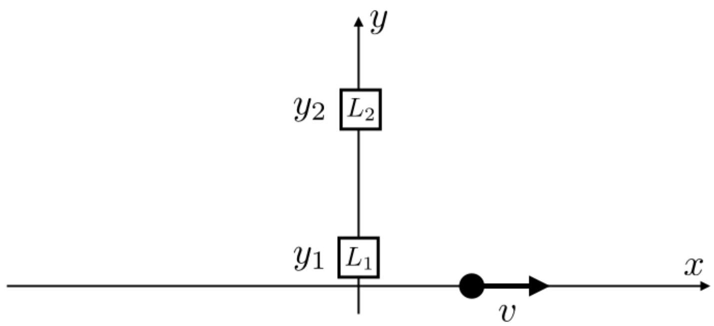
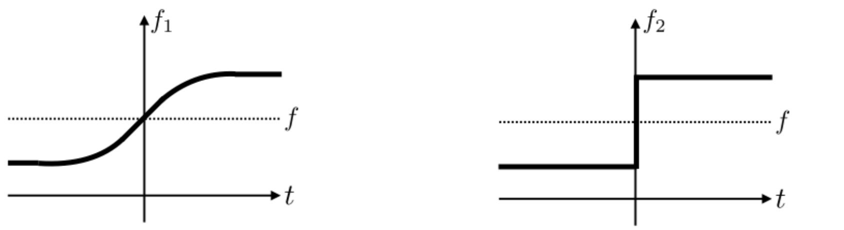
**Problem 1: [15pts] Concept questions: a) [5pts]**




A loudspeaker (black dot in figure above) is traveling along the $x$-axis from left to right with speed $v > 0$. Assume that $v$ is less than the speed of sound in air. The coordinates of the loudspeaker are $(x, y) = (vt, 0)$, and it is emitting sound of a constant frequency $f$. Two stationary listeners $L_1$, $L_2$ are sitting on the positive $y$-axis at coordinates $(0, y_1)$ and $(0, y_2)$ respectively: $L_1$ is very close to the $x$-axis, while $L_2$ is further away (see figure). Which of the following graphs describes the frequencies $f_1$ and $f_2$ heard by the listeners $L_1$ and $L_2$ as a function of time $t$. Note: in the figures below, the solid lines represent $f_1$, $f_2$, while the dotted horizontal lines represent the frequency $f$ of the loudspeaker.

**(1)**

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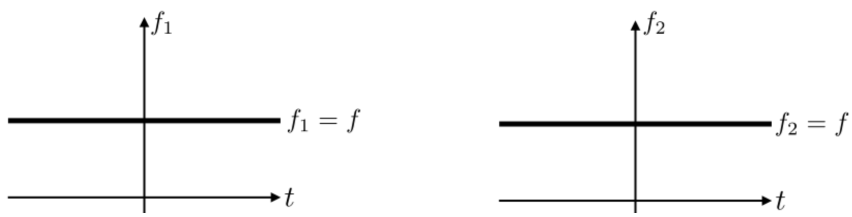

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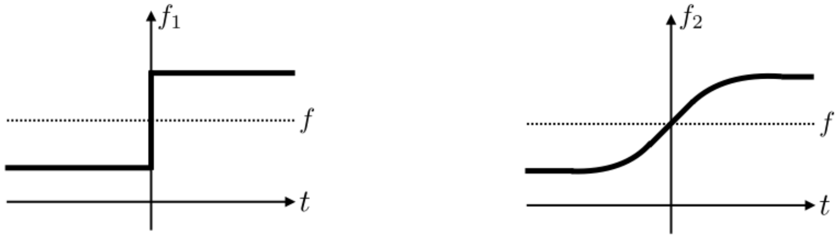


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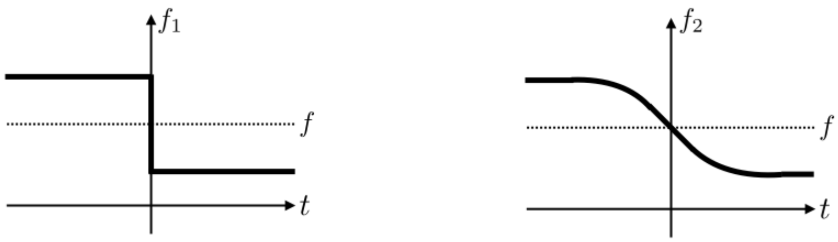


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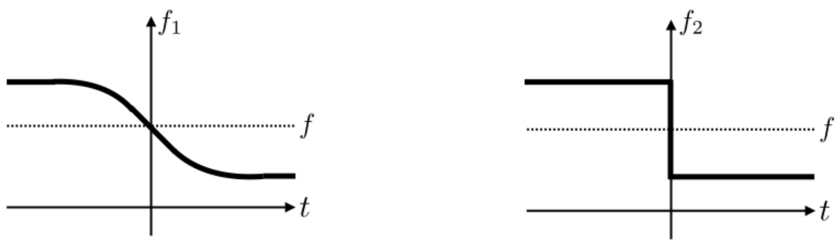
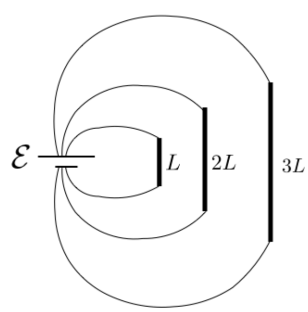



**b)** [**5pts**] Consider three identical pieces of thick wire with resistance $R$, length $L$ and cross-sectional area $A$. Now two of the wires are slowly stretched (without breaking) to lengths $2L$ and $3L$, without affecting their resistivity or density. (Think carefully about what this means for the shape and resistance of the stretched wires.) The three wires (indicated by thick lines in the figure below, which are not drawn to scale) are then connected to an ideal battery with e.m.f. $\mathcal{E}$ using ideal wires of zero resistance (indicated by thin lines in the figure).



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Which of the following equations are satisfied by the current densities $J_1$, $J_2$, $J_3$ in the wires of lengths $L$, $2L$, $3L$ respectively?

**(1)** $J_1 = J_2 = J_3$

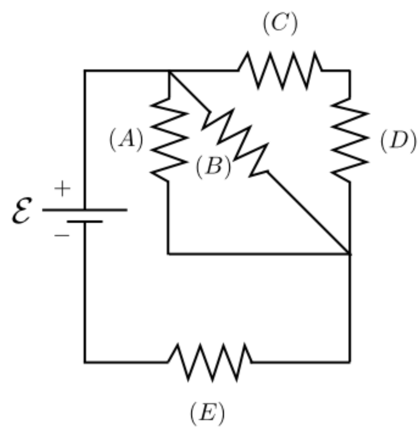
**(2)** $J_1 = 2J_2 = 3J_3$

**(3)** $J_1 = 4J_2 = 9J_3$

**(4)** $J_1 = \frac{1}{2}J_2 = \frac{1}{3}J_3$

**(5)** $J_1 = \frac{1}{4}J_2 = \frac{1}{9}J_3$

**c)** [**5pts**] The circuit below contains five identical resistors, labeled $(A)$ through $(E)$, of resistance $R$, driven by an ideal battery with e.m.f. $\mathcal{E}$.




Which statement is true about the powers $P_A$ through $P_E$ dissipated in resistors $(A)$ through $(E)$:

**(1)** $P_A = P_B = P_C = P_D = P_E$

**(2)** $P_A = P_B < P_C = P_D < P_E$

**(3)** $P_E < P_A = P_B < P_C = P_D$

**(4)** $P_A < P_B = P_C < P_D = P_E$

**(5)** $P_C = P_D < P_A = P_B < P_E$

**Problem 2:** **[30pts]** A police car $P$ is chasing a truck $T$. Both are driving in the same direction, with speeds $v_P$ and $v_T$, respectively. Assume that $0 \leq v_T \leq v_P < v_S$, where $v_S$ is the speed of sound in air.


The police car $P$ emits siren sounds at frequency $f_P$, which reflect off the back of the truck and travel back to $P$.

**a)** **[15pts]** Find a formula for the frequency $f'_P$ of the reflected siren sound received by the police car. Show your reasoning.

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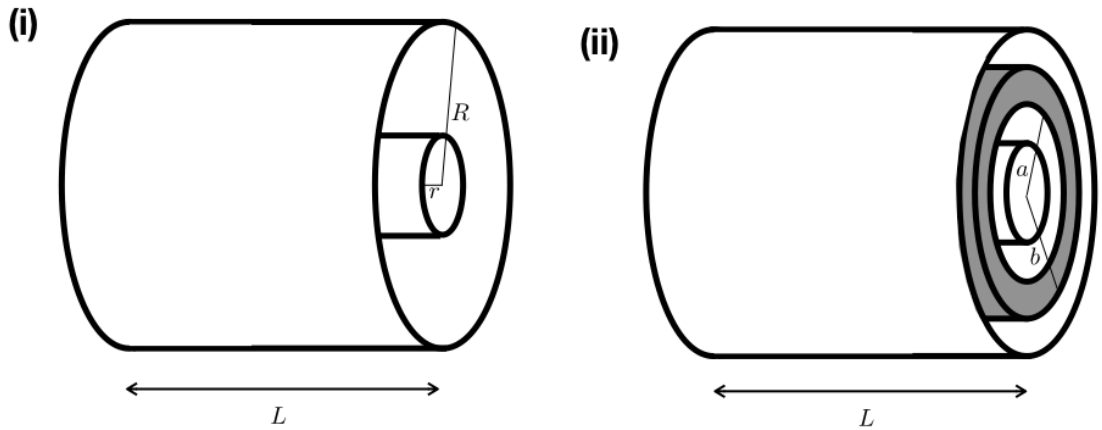
**b) [15pts]** Find a formula for the beat frequency heard by the police car; simplify your formula by assuming that $v_P, v_T \ll v_S$ (this is a good assumption, given that $v_S = 343\frac{\text{m}}{\text{s}} = 767\text{mph}$) and Taylor expanding. (Hint: since the speed of sound is large, you can take the small expansion parameter to be $\frac{1}{v_S}$.) In your own words, explain why the beat frequency vanishes when $v_P = v_T$.

**Problem 3:** [**30pts**] Consider a cylindrical capacitor consisting of two concentric cylinders of radii $r < R$ and length $L$, which are separated by vacuum (see figure (i) below). Its capacitance is given by $C = 2\pi\epsilon_0 \frac{L}{\ln\left(\frac{R}{r}\right)}$.




**a)** [**10pts**] A solid metal (i.e. conducting) cylinder of inner radius $a$ and outer radius $b$, with $r < a \leq b < R$, and length $L$ is now inserted in between, and concentric with, the plates of the capacitor (see figure (ii) above; the metal cylinder is indicated in solid grey). Assume that the metal cylinder does not itself carry any net charge. What is the capacitance of this new configuration? Show your reasoning.

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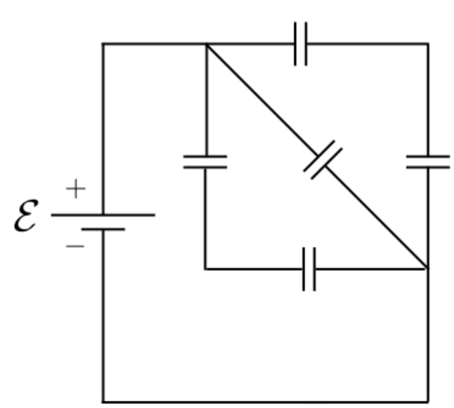
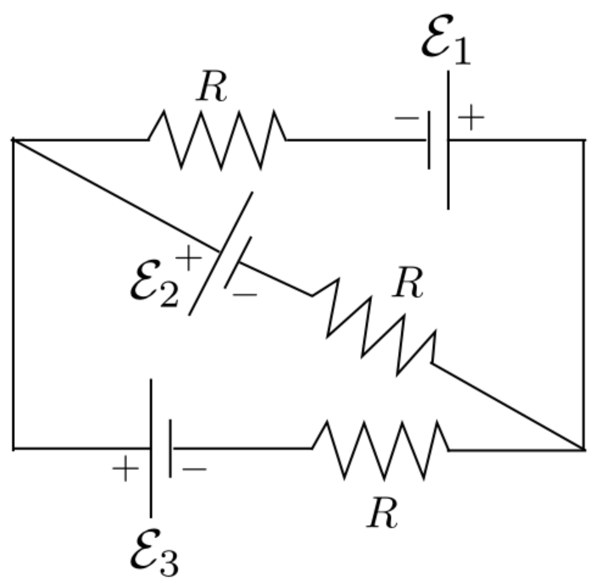
**b) [10pts]** Consider the capacitor in figure (ii) above with zero initial charge. A charge $Q$ is then deposited on the capacitor, e.g. by hooking up a battery to its inner and outer plates (at radii $r$ and $R$) and then disconnecting the battery once the capacitor reaches charge $Q$. What condition must the radii $a$ and $b$ of the metal cylinder satisfy in order to maximize the energy stored by the capacitor as a function of $a$ and $b$? Explain the meaning of your result.

**c) [10pts]** Consider five identical capacitors of capacitance $C$ connected to an ideal battery of e.m.f. $\mathcal{E}$:



**3c) continued:** Find the equivalent capacitance of these five capacitors. How much total energy do these capacitors store once they are fully charged by the battery?

**Problem 4: [30pts]** Consider the follwing circuit, which contains three identical resistors of resistance $R$, and three batteries whose polarities are as shown, with e.m.f.'s $\mathcal{E}_1, \mathcal{E}_2, \mathcal{E}_3 > 0$.



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**a) [10pts]** Assign labels and directions for all currents in the circuit. (Redraw the figure above if needed.) Then apply the junction rule to eliminate as many currents as possible.

**b) [10pts]** Apply the loop rule to write down enough independent equations so that it is possible to solve for the remaining unknown currents. Indicate clearly which loops you are choosing. Note: you do not need to explicitly solve the equations in this part of the problem.

**c) [10pts]** What condition must $\mathcal{E}_1, \mathcal{E}_2, \mathcal{E}_3$ satisfy so that the current through $\mathcal{E}_3$ vanishes? Assuming this condition is satisfied, find the magnitude and the direction of the current through $\mathcal{E}_2$.

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