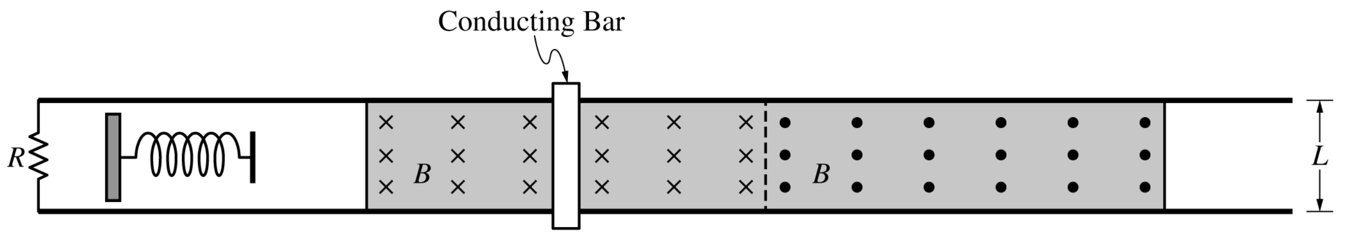
Begin your response to **QUESTION 2** on this page.



Top View (at time t_B)

2. Two horizontal, parallel, conducting rails are separated by distance $L = 0.40$ m. A resistor of resistance $R = 0.30\ \Omega$ connects the rails. A horizontal ideal spring is located between the rails. The right end of the spring is free to move and the left end is fixed in place. A conducting bar of mass $m = 0.23$ kg is placed on the rails and is in contact with the spring, which is initially compressed. Frictional forces and the resistance of the bar and rails are negligible.

- At time $t = 0$, the bar is released from rest and is pushed to the right by the spring.
- At time t_1, the bar loses contact with the spring and slides to the right.
- At time t_2, the bar enters and travels through a uniform magnetic field of magnitude $B = 0.50$ T that is directed into the page, as shown.
- At time t_3, the bar enters a region where the magnitude of the uniform magnetic field is still $B = 0.50$ T but is directed out of the page.
- At time t_4, the bar enters a region with no magnetic field.

Consider time t_B such that $t_2 < t_B < t_3$.

(a) On the following diagram of the bar, draw an arrow indicating the direction of the net force F_{net} exerted on the bar at time t_B. If the net force is zero, write $F_{net} = 0$.

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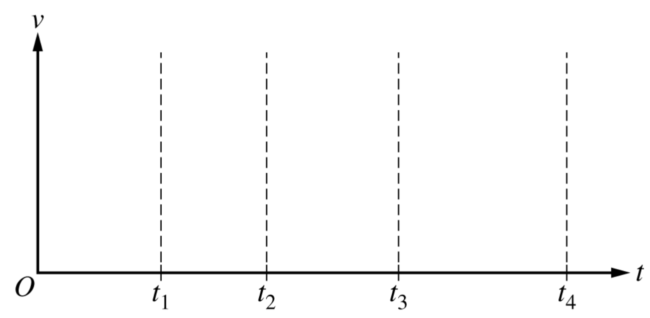
Continue your response to **QUESTION 2** on this page.

(b) At time t_B, the speed of the bar is $v = 2.5$ m/s.

i. Calculate the magnitude of the current in the bar at time t_B.

ii. Calculate the magnitude of the net force F_{net} exerted on the bar at time t_B.

(c) On the following axes, sketch a graph of the speed v of the bar as a function of time t between $t = 0$ and t_4.



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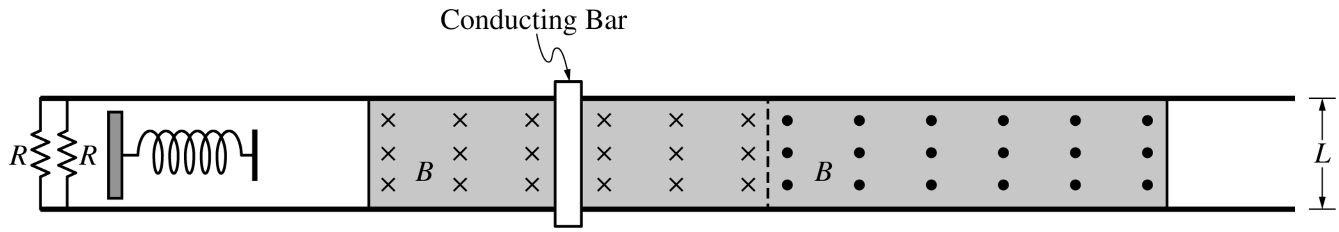
Continue your response to **QUESTION 2** on this page.



Top View (at time t_B)

(d) The scenario is repeated but an additional resistor of resistance $R = 0.30\ \Omega$ is connected, as shown.

i. Determine the total resistance R_{total} of the closed circuit for the new scenario.

ii. In the original scenario, the magnitude of the acceleration of the bar immediately after the bar enters the first uniform magnetic field is $a_{original}$. In the new scenario, the magnitude of the acceleration of the bar immediately after the bar enters the first uniform magnetic field is a_{new}. Is a_{new} greater than, less than, or equal to $a_{original}$? Justify your answer.

(e) Describe a modification to m, B, or L that will result in a smaller induced potential difference across the original resistor immediately after the bar enters the first uniform magnetic field. Justify your answer.

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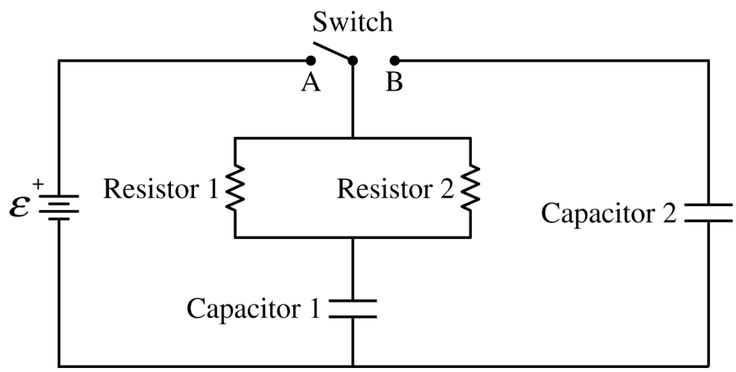
Begin your response to **QUESTION 3** on this page.



3. The circuit shown consists of a battery of emf $\mathcal{E}$, resistors 1 and 2 each with resistance R, capacitors 1 and 2 with capacitances C and $2C$, respectively, and a switch. The switch is initially open and both capacitors are uncharged.

At time $t = 0$, the switch is closed to Position A.

(a) Write, but do NOT solve, a differential equation that can be used to determine the charge Q on the positive plate of Capacitor 1 as a function of time t after the switch is closed to Position A. Express your answer in terms of $\mathcal{E}$, R, C, Q, t, and fundamental constants, as appropriate.

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(e)	For correctly indicating **one** of the following, with an attempt at a relevant justification: • Decreasing B • Decreasing L • Increasing m	**1 point**
	For correctly justifying the identified modification that will result in a smaller induced potential difference across the original resistor	**1 point**

Example Responses

The potential difference due to the induced emf *across the original resistor is described by the equation* $\mathcal{E} = -BLv$. *Induced potential difference* $\mathcal{E}$ *is proportional to* B. *Therefore, if the magnitude of the magnetic field is smaller than* $B = 0.5\ \mathrm{T}$ *in the new scenario compared to the original scenario,* $\mathcal{E}$ *would be smaller.*

OR

The potential difference due to the induced emf *across the original resistor is described by the equation* $\mathcal{E} = -BLv$.*The induced potential difference* $\mathcal{E}$ *is proportional to* L, *which represents the distance the conducting rails are separated. Therefore, if* L *is smaller than* $L = 0.4\ \mathrm{m}$, $\mathcal{E}$ *would be smaller.*

OR

The potential difference due to the induced emf *across the original resistor is described by the equation* $\mathcal{E} = -BLv$. *If the mass of the bar is greater, the velocity entering the magnetic field is less. The induced potential difference* $\mathcal{E}$ *is proportional to* v. *Therefore, a smaller* v *due to a greater mass will induce a smaller* $\mathcal{E}$.

Total for part (e) 2 points

Total for question 2 15 points