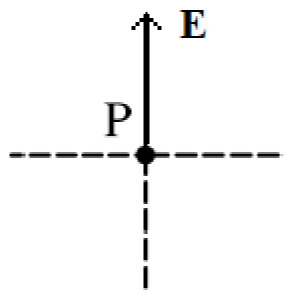
2019 AP Physics C Electricity and Magnetism Free Response

1a.i.



1a.ii. The Gaussian surface should be a cylinder with its axis centered along the thin, non-conducting wire.

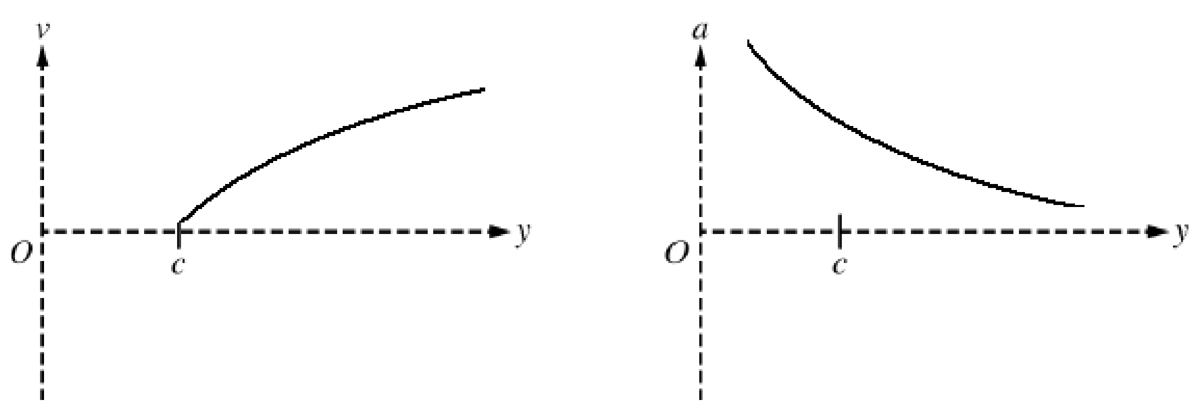
1a.iii.

$Q_{enclosed} = \varepsilon_0 \cdot \oiint E \cdot dA$

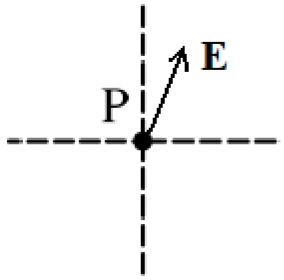
$\lambda \cdot L = E \cdot L \cdot 2\pi \cdot c$

$E = \frac{\lambda}{2\pi\varepsilon_0 c}$

1b.



1c.



1d. No. The same Gaussian cylinder described in 1a would not work in this situation. Electric field lines would pass through the sides of the cylinder and would not be accounted for in the integral which is only over the side of the cylinder.

1e. The vertical component equation is incorrect. One error is that the differential should be dx instead of dy because λ is being integrated along the x-axis. A second error is that the y in the numerator should be the constant value c because the point where the electric field is being measured is a constant vertical distance c from the wire.

2a.i.

$I_1 + I_3 = I_2$

$0 = 6 - 150I_1 - 200I_2$

$0 = 6 - 100I_3 - 200I_2$

2a.ii. $I_2 = 0.023077A$

2.a.iii. $P = -I^2R = -0.1065W$

2b. $I_{50} = \frac{4.4}{150} = 0.2933A$

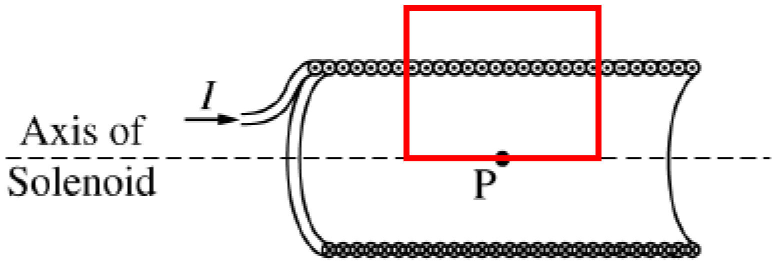
2c. $V = 4.4 + (0.0513)(150) = 12.1V$

2d.i. $I = \frac{12.1}{200} = 0.0605A$

2d.ii.Less than. In the steady state, there is no voltage across the inductor and the middle branch acts as a bare wire. The net resistance of the circuit is then less than it was in part (b), making the current through the 150Ω resistor higher and the voltage across that resistor higher as well. By the loop rule, the voltage across the right branch resistors must be less, implying that their current is less as well.

3a. +x direction. Using one of the right-hand rules, if the right-hand is oriented so that the fingers curl with the direction of the current along the solenoid, the thumb indicates the direction of the magnetic field inside the solenoid.

3b.



Cutaway View

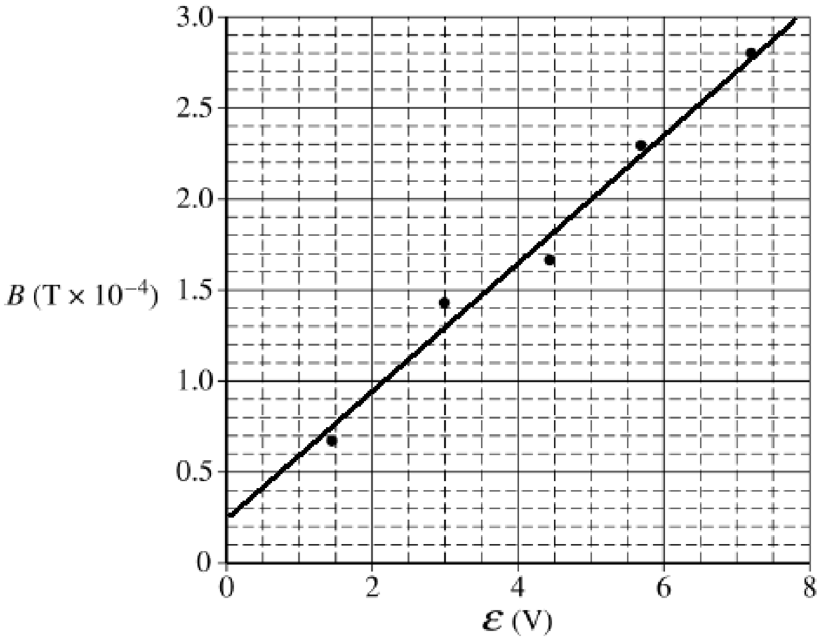
3b.ii.

$\mu_0 \cdot I_{enclosed} = \oint B \cdot dl$

$\mu_0 \cdot I \cdot N = B \cdot L$

$B = \frac{\mu_0 I N}{L}$

3c.i.



3c.ii. B = $\frac{\mu_0 IN}{L}$ = $\frac{\mu_0 VN}{RL}$ so slope = $\frac{B}{V}$ = $\frac{\mu_0 N}{RL}$

3.55E-5 = $\frac{(4\pi E-7)(100)}{(R)(0.40)}$ so R = 8.85Ω

3d.i. Yes, the graph does have a non-zero y-intercept which indicates that even when the applied voltage is zero, the magnetic field sensor is reading the magnetic field of the Earth.

3d.ii. No. The slope of the graph is independent of the y-intercept and the slope of the graph was used to determine the resistance.

3e.i. Clockwise. The rightward field inside the solenoid is decreasing. By Lenz's law, the induced current in the thin loop must create a rightward magnetic field. By the right-hand rule, this induced current must be clockwise according to the diagram.

3e.ii.

I_{Ind} = $\frac{V}{R_L}$ where |V| = $\frac{d\Phi}{dt}$ = A·$\frac{dB}{dI}$·$\frac{dI}{dt}$ = πa^2·$\frac{\mu_0 N}{L}$·$\frac{I}{\Delta t}$

I_{ind} = $\frac{\mu_0 \pi a^2 NI}{LR_L \Delta t}$