

Note: Figures not drawn to scale.

3. A solenoid is used to generate a magnetic field. The solenoid has an inner radius a , length ℓ , and N total turns of wire. A power supply, not shown, is connected to the solenoid and generates current I , as shown in the figure on the left above. The x -axis runs along the axis of the solenoid. Point P is in the middle of the solenoid at the origin of the xyz -coordinate system, as shown in the cutaway view on the right above. Assume $\ell \gg a$.

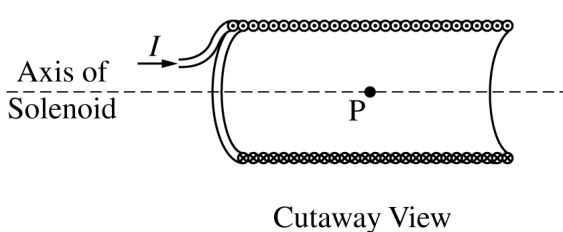
(a) Select the correct direction of the magnetic field at point P.

☐ $+x$ -direction ☐ $+y$ -direction ☐ $+z$ -direction
☐ $-x$ -direction ☐ $-y$ -direction ☐ $-z$ -direction

Justify your selection.

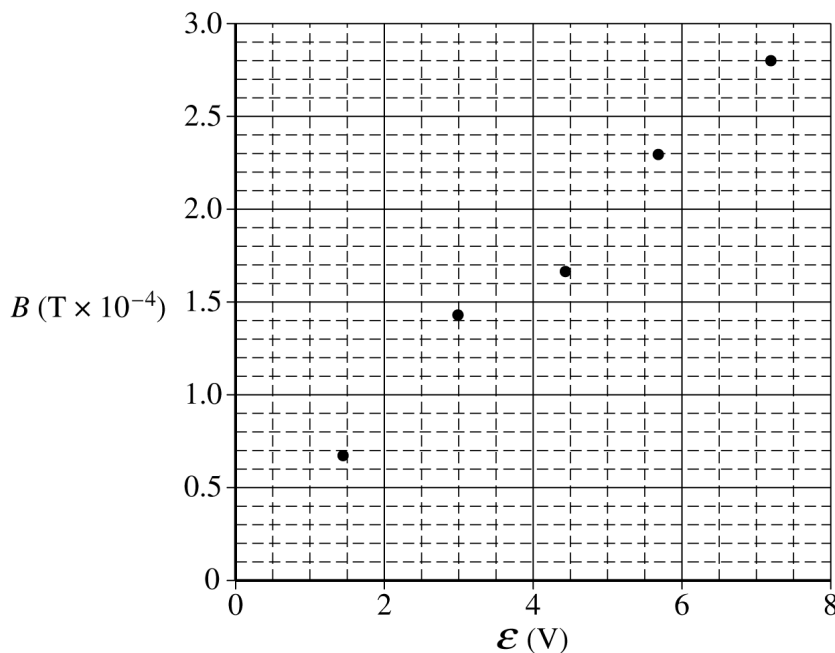
(b)

- i. On the cutaway view below, clearly draw an Amperian loop that can be used to determine the magnetic field at point P at the center of the solenoid.



- ii. Use Ampere's law to derive an expression for the magnetic field strength at point P. Express your answer in terms of I , ℓ , N , a , and physical constants, as appropriate.

Some physics students conduct an experiment to determine the resistance R_S of a solenoid with radius $a = 0.015$ m, total turns $N = 100$, and total length $\ell = 0.40$ m. The students connect the solenoid to a variable power supply. A magnetic field sensor is used to measure the magnetic field strength along the central axis at the center of the solenoid. The plot of the magnetic field strength B as a function of the emf $\mathcal{E}$ of the power supply is shown below.



(c)

- i. On the graph above, draw a best-fit line for the data.
 ii. Use the straight line to determine the resistance R_S of the solenoid used in the experiment.

(d) One of the students notes that the horizontal component of the magnetic field of Earth is 2.5×10^{-5} T.

- i. Is there evidence from the graph that the horizontal orientation of the solenoid affects the measured values for B ?

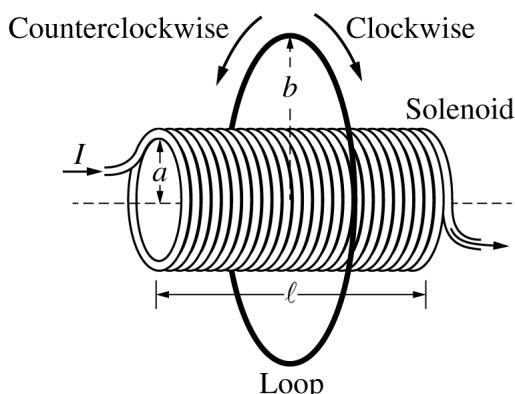
☐ Yes ☐ No

Justify your answer.

- ii. Would the horizontal orientation of the solenoid affect the calculated value for R_S ?

☐ Yes ☐ No

Justify your answer.



A thin conducting loop of radius b and resistance R_L is placed concentric with the solenoid, as shown above. The current in the solenoid is decreased from I to zero over time Δt .

(e)

- i. Is the direction of the induced current in the loop clockwise or counterclockwise during the time period that the current in the solenoid is decreasing?

☐ Clockwise ☐ Counterclockwise

Justify your answer.

- ii. Derive an equation for the average induced current i_{IND} in the loop during the time period that the current in the solenoid is decreasing. Express your answer in terms of I , ℓ , N , a , b , R_L , R_S , Δt , and physical constants, as appropriate.

STOP
END OF EXAM