AP® Physics C: Electricity and Magnetism
2005 Sample Student Responses

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1A

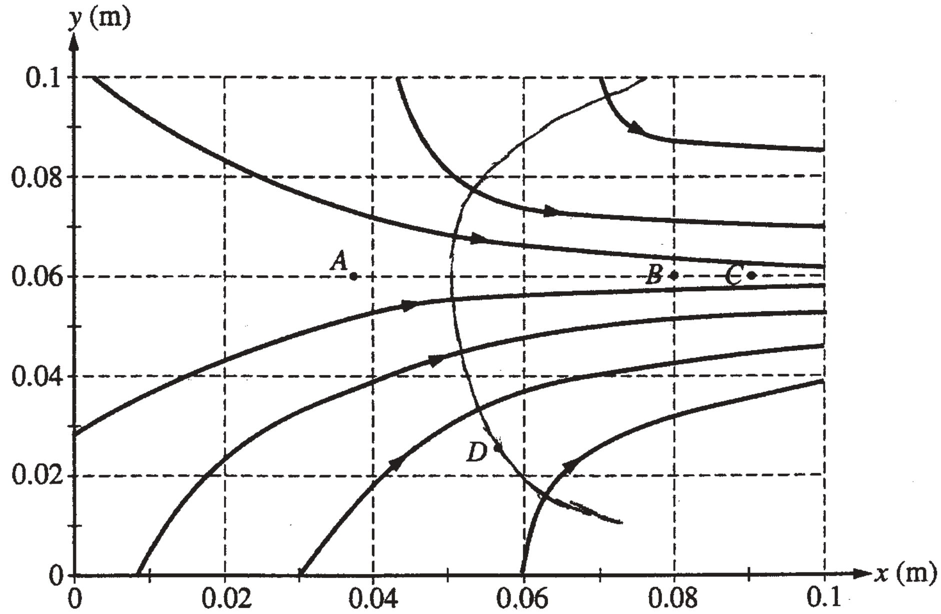
PHYSICS C

Section II, ELECTRICITY AND MAGNETISM

Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



E&M. 1.

Consider the electric field diagram above.

(a) Points A, B, and C are all located at $y = 0.06$ m .

i. At which of these three points is the magnitude of the electric field the greatest? Justify your answer.

At Point C because the density of the field lines is greatest,

ii. At which of these three points is the electric potential the greatest? Justify your answer.

At Point A. because the field points from greater to less potential.

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1A

(b) An electron is released from rest at point *B*.

i. Qualitatively describe the electron's motion in terms of direction, speed, and acceleration.

It would feel a force to the left. As it moves to left with increasing speed, the acceleration gets less and less so that the particle reaches a terminal velocity

ii. Calculate the electron's speed after it has moved through a potential difference of 10 V.

$W = Vq$

$\Delta KE = Vq$

$\frac{1}{2}mv^2 - \frac{1}{2}m(0^2) = 10 \cdot q$

$v^2 = \frac{20q}{m}$ $\quad v = \sqrt{\frac{20q}{m}} = 1.87 \times 10^6$ m/s

(c) Points *B* and *C* are separated by a potential difference of 20 V. Estimate the magnitude of the electric field midway between them and state any assumptions that you make.

I shall assume that the rate of change of V (potential) is constant.

$|E| = \frac{dV}{dx} = \frac{20}{0.09-0.08} = \frac{20}{0.01} = 2000$ N/C

(d) On the diagram, draw an equipotential line that passes through point *D* and intersects at least three electric field lines.

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E E E E E E E E E E E E E E E E E

1B

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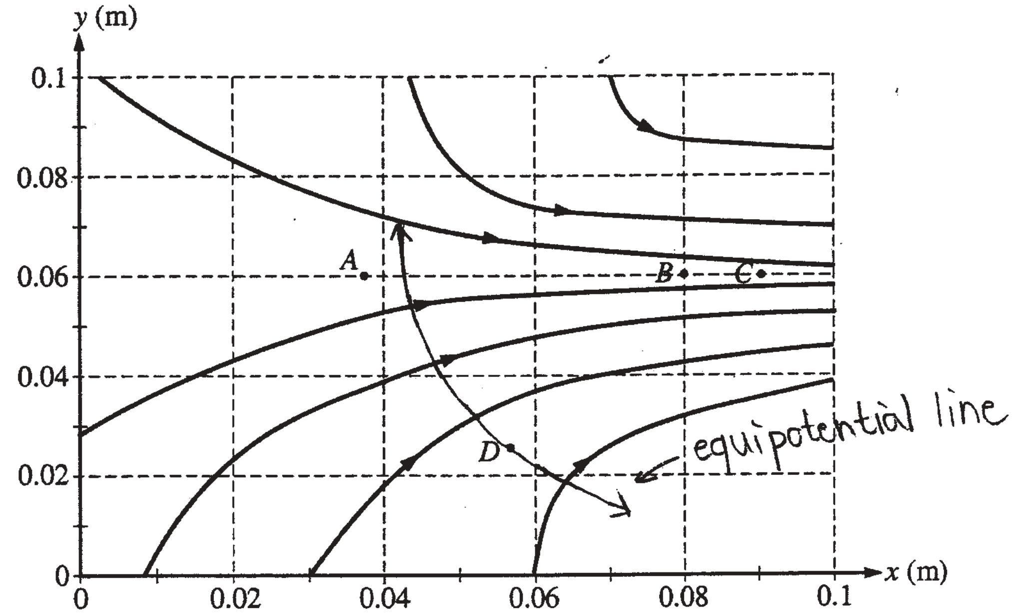

E&M. 1.

Consider the electric field diagram above.

(a) Points A, B, and C are all located at $y = 0.06$ m.

i. At which of these three points is the magnitude of the electric field the greatest? Justify your answer.

By inspection, the electric field lines at C is most dense. ∴ the magnitude of the electric field is greatest at C.

ii. At which of these three points is the electric potential the greatest? Justify your answer.

A is the point with the greatest potential since its the furthest away. More work is required to bring this charge to A.

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(b) An electron is released from rest at point *B*.

i. Qualitatively describe the electron's motion in terms of direction, speed, and acceleration.

The electron will be accelerated towards East at a straight line. The acceleration increases as it moves and so does its speed.

ii. Calculate the electron's speed after it has moved through a potential difference of 10 V.

$$\Delta qV = \Delta U_E = \frac{1}{2}mv^2$$

$$1.60\times10^{-19}\times10 = \frac{1}{2}(9.11\times10^{-31})v^2$$

$$v = 1.87\times10^{6}\ m/s$$

(c) Points *B* and *C* are separated by a potential difference of 20 V. Estimate the magnitude of the electric field midway between them and state any assumptions that you make.

Assuming that the other charges and the external electric field has no effect and the field is uniform,

$$V = Ed$$

$$\frac{20}{0.01} = E$$

$$E = 2000\ N/C$$

(d) On the diagram, draw an equipotential line that passes through point *D* and intersects at least three electric field lines.

GO ON TO THE NEXT PAGE.

1C

PHYSICS C

Section II, ELECTRICITY AND MAGNETISM

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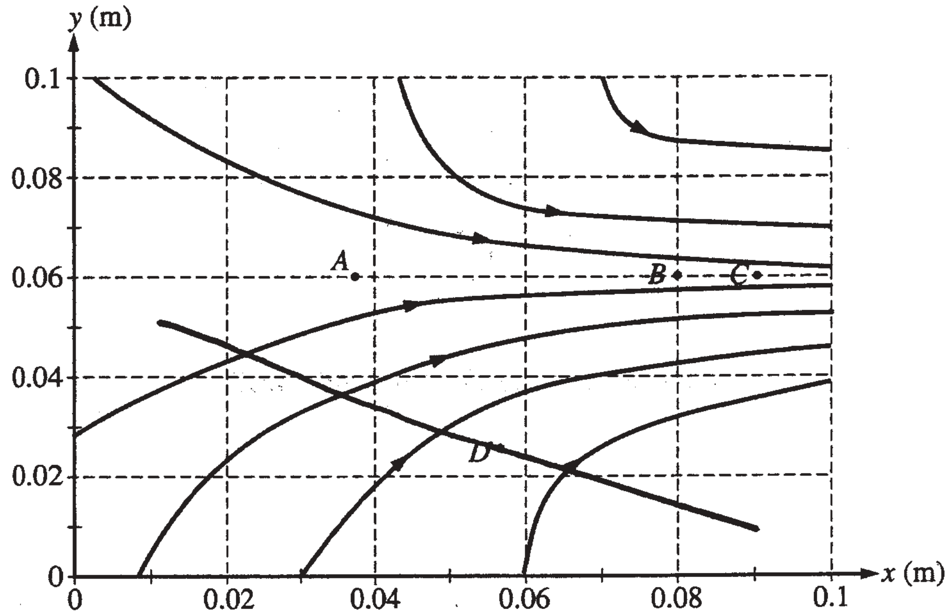

E&M. 1.

Consider the electric field diagram above.

(a) Points *A*, *B*, and *C* are all located at $y = 0.06$ m .

i. At which of these three points is the magnitude of the electric field the greatest? Justify your answer.

C b/c E lines ar closest togather

ii. At which of these three points is the electric potential the greatest? Justify your answer.

None, all equidistant from $\vec{E}$ field lines so net force is 0

GO ON TO THE NEXT PAGE.

(b) An electron is released from rest at point *B*.

i. Qualitatively describe the electron's motion in terms of direction, speed, and acceleration.

Since E field lines point toward the dir a proton would be pushed, an e^- would move neg. in X direction, 0 on y-axis, the speed would increase until ∞ far away. Acc. would be at a max at the beginning & die off the farther away it goes. It is zero only @ ∞.

ii. Calculate the electron's speed after it has moved through a potential difference of 10 V.

$E = \frac{F}{q}$ $10V = \frac{F}{e^-}$ $1.6\times10^{-19}\ N = F$?

V_f - $V_f = V_i t$

$V_i = 0$

$a = 1.6\times10^{-19}$

Δt =

Δx =

$V = \frac{F}{R}$

$1.774\times10^{-29}\ m/s$

(c) Points *B* and *C* are separated by a potential difference of 20 V. Estimate the magnitude of the electric field midway between them and state any assumptions that you make.

20V → assumptions: 1- I'm making my own physics laws

Seriously → 2 - It is the same electric field thru out

3 - e.f. lines are evenly spaced?

(d) On the diagram, draw an equipotential line that passes through point *D* and intersects at least three electric field lines.

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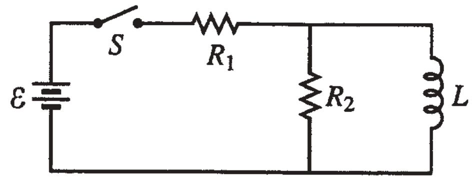
2A



E&M. 2.

In the circuit shown above, resistors 1 and 2 of resistance R_1 and R_2, respectively, and an inductor of inductance L are connected to a battery of emf $\mathcal{E}$ and a switch S. The switch is closed at time $t = 0$. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Determine the current through resistor 1 immediately after the switch is closed.

$R_{eq} = R_1 + R_2$

$V = IR$

$I = \mathcal{E}/(R_1 + R_2)$ A

(b) Determine the magnitude of the initial rate of change of current, dI/dt, in the inductor.

$$\mathcal{E} = -L \frac{dI}{dt}$$

$$\frac{dI}{dt} = \frac{\mathcal{E}}{L}$$

$$\frac{dI}{dt} = \frac{R_2\left(\frac{\mathcal{E}}{R_1 + R_2}\right)}{L}$$

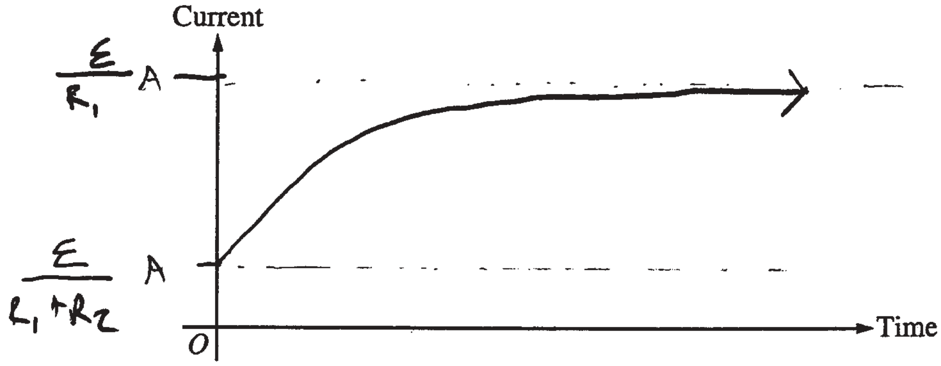
GO ON TO THE NEXT PAGE.

(c) Determine the current through the battery a long time after the switch has been closed.

$V=IR$

$I = \mathcal{E}/R_1$ A

(d) On the axes below, sketch a graph of the current through the battery as a function of time.



Some time after steady state has been reached, the switch is opened.

(e) Determine the voltage across resistor 2 just after the switch has been opened.

$V=IR$

$V = \left(\frac{\mathcal{E}}{R_1}\right) R_2$ V

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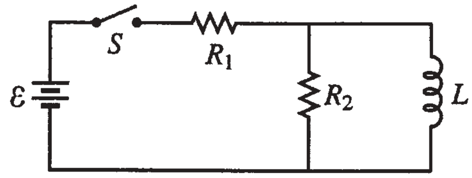
2B



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(a) Determine the current through resistor 1 immediately after the switch is closed.

Inductor acts as ∞ Resistor.

$$I = \frac{\mathcal{E}}{R_1 + R_2}$$

$$\mathcal{E} = I(R_1 + R_2)$$

(b) Determine the magnitude of the initial rate of change of current, dI/dt, in the inductor.

$$V = L\frac{dI}{dt}$$

$$V = IR$$

$$\frac{\mathcal{E}R_2}{R_1 + R_2} = L\frac{dI}{dt}$$

$$\frac{\mathcal{E}R_2}{L(R_1 + R_2)} = \frac{dI}{dt}$$

GO ON TO THE NEXT PAGE.

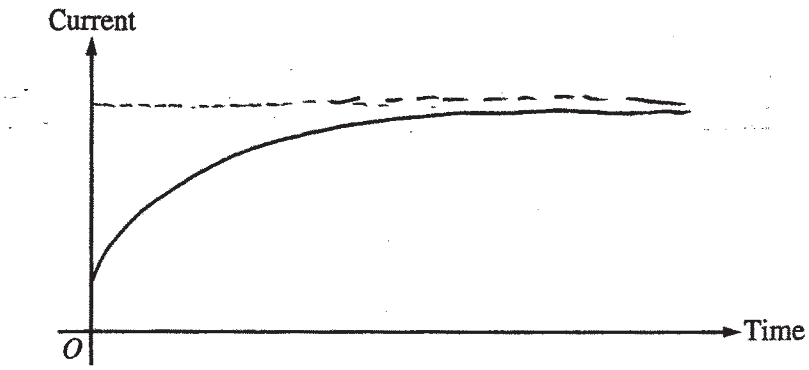
(c) Determine the current through the battery a long time after the switch has been closed.

$I = \frac{\mathcal{E}}{R_1}$

Inductor acts as wire, Path of no resistance.

$\mathcal{E} = IR_1$

(d) On the axes below, sketch a graph of the current through the battery as a function of time.



Some time after steady state has been reached, the switch is opened.

(e) Determine the voltage across resistor 2 just after the switch has been opened.

$\frac{V}{I}: \frac{\mathcal{E}R_1}{R_1+R_2}$

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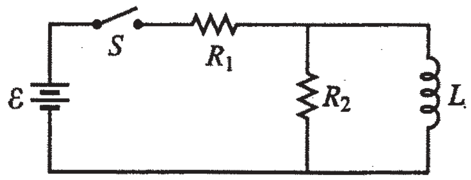
2C



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$$R_{eq} = R_1 + R_2$$

$$I_0 = \frac{\mathcal{E}}{R_1 + R_2}$$

(b) Determine the magnitude of the initial rate of change of current, dI/dt, in the inductor.

$$\mathcal{E} = -L\frac{dI}{dt}$$

$$\frac{dI}{dt} = -\frac{\mathcal{E}}{L}$$

GO ON TO THE NEXT PAGE.

$\frac{N}{A} = \frac{C}{s}$ $\frac{N \cdot s}{C^2}$

2C

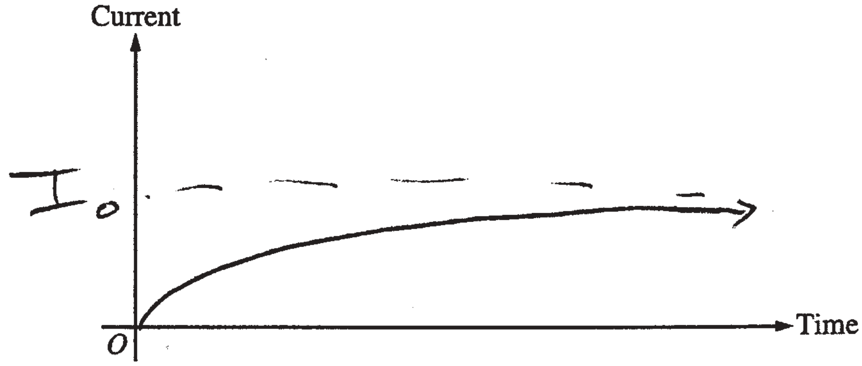
(c) Determine the current through the battery a long time after the switch has been closed.

~~$8\,dI = \int \varepsilon\, dt$~~

$$I(t) = I_0\left(1 - e^{-t\left(\frac{L}{R_{eq}}\right)}\right)$$

$$I(\infty) = I_0\left(1 - e^{-t\left(\frac{L}{R_1+R_2}\right)}\right) = I_0$$

(d) On the axes below, sketch a graph of the current through the battery as a function of time.



Some time after steady state has been reached, the switch is opened.

(e) Determine the ~~voltage across~~ resistor 2 just after the switch has been opened.

$$\boxed{\varepsilon - I_0 R_1 = V_{R2}}$$

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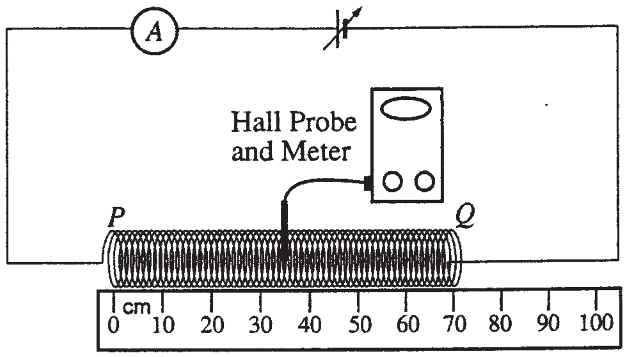

E&M. 3.

A student performs an experiment to measure the magnetic field along the axis of the long, 100-turn solenoid PQ shown above. She connects ends P and Q of the solenoid to a variable power supply and an ammeter as shown. End P of the solenoid is taped at the 0 cm mark of a meterstick. The solenoid can be stretched so that the position of end Q can be varied. The student then positions a Hall probe* in the center of the solenoid to measure the magnetic field along its axis. She measures the field for a fixed current of 3.0 A and various positions of the end Q. The data she obtains are shown below.

Trial	Position of End Q (cm)	Measured Magnetic Field (T) (directed from P to Q)	n (turns/m)
1	40	9.70×10^{-4}	250
2	50	7.70×10^{-4}	200
3	60	6.80×10^{-4}	167
4	80	4.90×10^{-4}	125
5	100	4.00×10^{-4}	100

(a) Complete the last column of the table above by calculating the number of turns per meter.

$\frac{100 \text{ turns}}{\text{position of End Q}}$ m

$\frac{100}{.4} = 250$ $\frac{100}{.5} = 200$ $\frac{100}{.6} = 167$

$\frac{100}{.8} =$ $\frac{100}{1} = 100$

* A Hall Probe is a device used to measure the magnetic field at a point.

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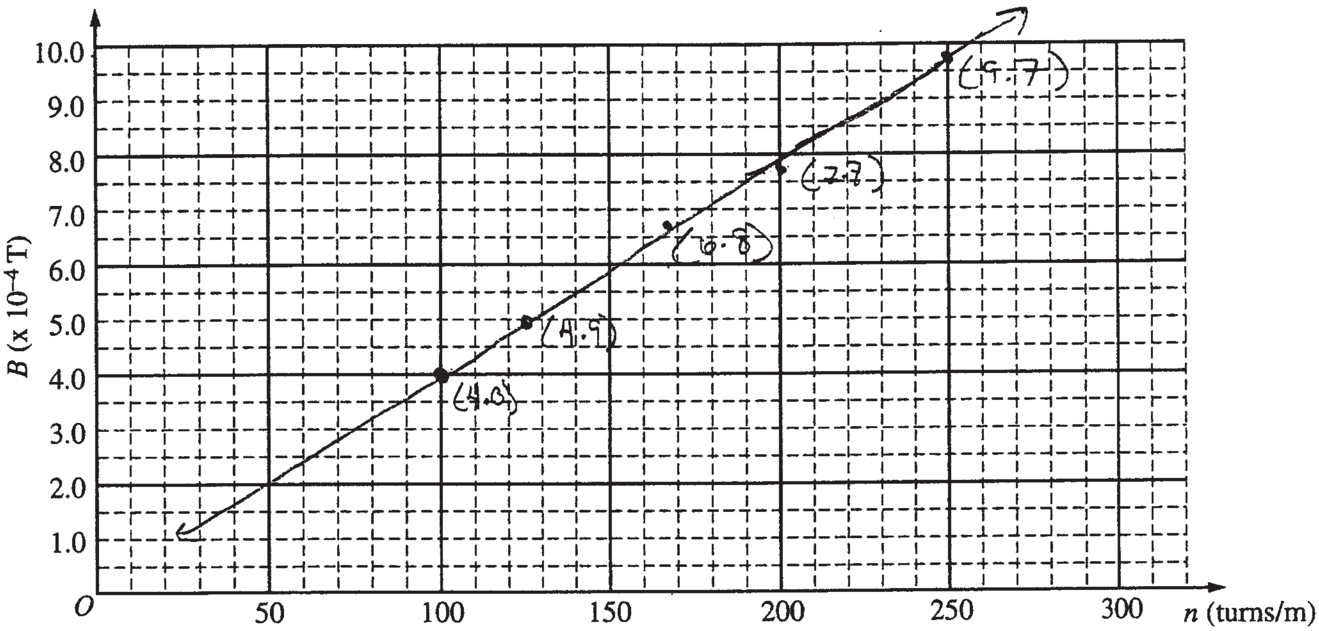
(b) On the axes below, plot the measured magnetic field B versus n. Draw a best-fit straight line for the data points.



(c) From the graph, obtain the value of μ_0, the magnetic permeability of vacuum.

$B = \mu_0 n I$

$\mu_0 = \frac{B}{nI} = \frac{B}{n}\left(\frac{1}{I}\right) =$

$\frac{(4.0 \times 10^{-6})}{3} = \boxed{1.33 \times 10^{-6}\ T \cdot m/A}$

$\frac{B}{n} = \frac{(9.7 - 7.7)}{(250 - 200)} = 4.0 \times 10^{-6}$

(d) Using the theoretical value of $\mu_0 = 4\pi \times 10^{-7}$ (T•m)/A, determine the percent error in the experimental value of μ_0 computed in part (c).

$\frac{\text{experiment} - \text{actual}}{\text{actual}} = \frac{(1.33 \times 10^{-6} - 4\pi \times 10^{-7})}{(4\pi \times 10^{-7})} = 0.0584$

$\boxed{5.84\%\ \text{error}}$

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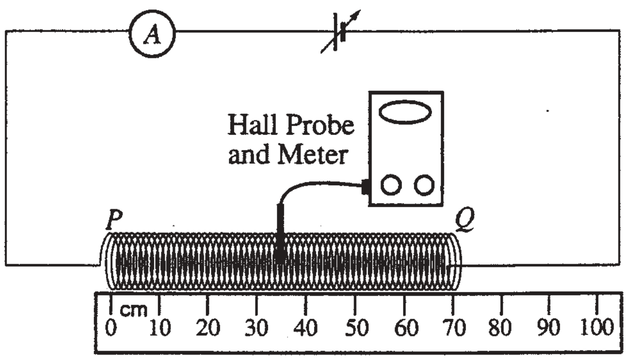
3B



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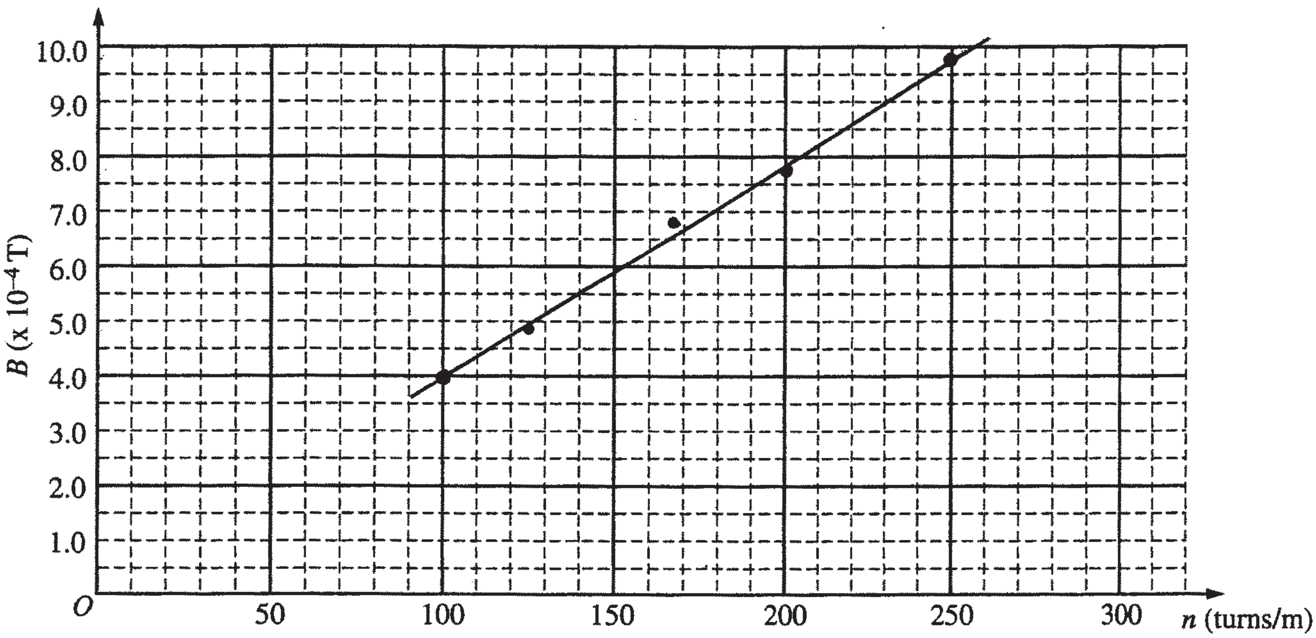

(c) From the graph, obtain the value of μ_0, the magnetic permeability of vacuum.

$$B = \mu_0 n I$$

$$\mu_0 = \frac{B}{3n} = 1.31 \times 10^{-6}$$

(d) Using the theoretical value of $\mu_0 = 4\pi \times 10^{-7}$ (T•m)/A, determine the percent error in the experimental value of μ_0 computed in part (c).

$$\% \text{ error} = \frac{\text{Actual Value} - \text{Theoretical}}{\text{Actual}} = .041 = 4.1\%$$

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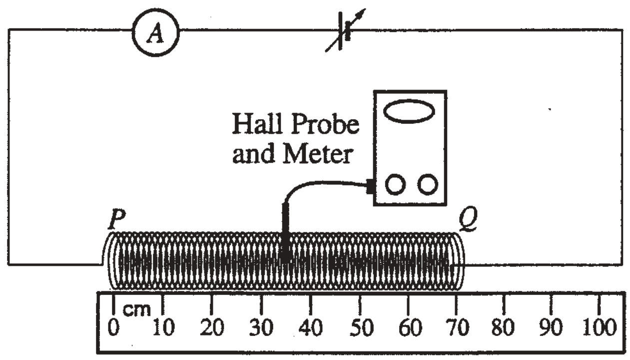
3C



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3	60	6.80×10^{-4}	
4	80	4.90×10^{-4}	
5	100	4.00×10^{-4}	

(a) Complete the last column of the table above by calculating the number of turns per meter.

$B = \mu n I$

$n = \dfrac{B}{\mu I}$

Trial	n turns
1	257.3
2	204.25
3	180.38
4	129.98
5	106.10

*A Hall Probe is a device used to measure the magnetic field at a point.

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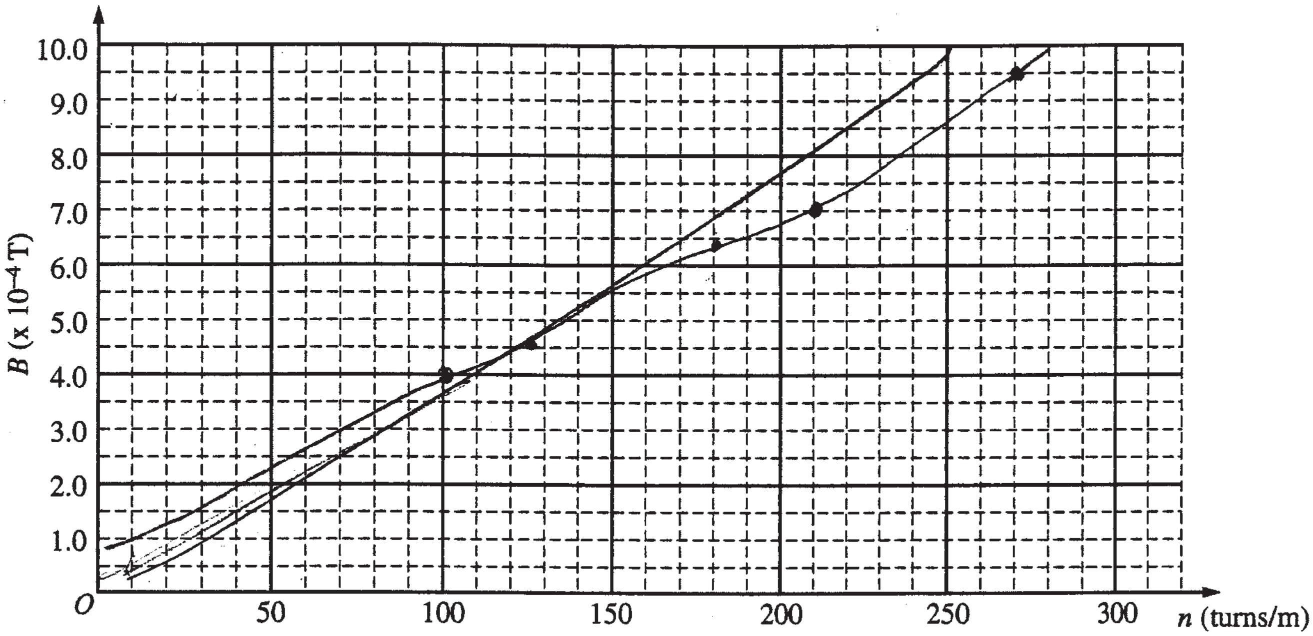
(b) On the axes below, plot the measured magnetic field B versus n. Draw a best-fit straight line for the data points.



(c) From the graph, obtain the value of μ_0, the magnetic permeability of vacuum.

$$\mu_0 = \frac{dy}{dx} = \frac{\Delta y}{\Delta x} = \boxed{1,256 \times 10^{-6}} = \mu_0$$

(d) Using the theoretical value of $\mu_0 = 4\pi \times 10^{-7}$ (T•m)/A, determine the percent error in the experimental value of μ_0 computed in part (c).

$$\% \text{ Error} = \left| \frac{\text{Observed} - \text{Accepted}}{\text{Accepted}} \right| \times 100$$

$$\boxed{\% \text{ Error} = .051 \%}$$

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