



AP[®] Physics C: Electricity and Magnetism 2005 Free-Response Questions

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TABLE OF INFORMATION FOR 2005

CONSTANTS AND CONVERSION FACTORS		UNITS		PREFIXES		
		Name	Symbol	Factor	Prefix	Symbol
1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$			10^9	giga	G
	$= 931 \text{ MeV}/c^2$	meter	m	10^6	mega	M
Proton mass,	$m_p = 1.67 \times 10^{-27} \text{ kg}$	kilogram	kg	10^3	kilo	k
Neutron mass,	$m_n = 1.67 \times 10^{-27} \text{ kg}$	second	s	10^{-2}	centi	c
Electron mass,	$m_e = 9.11 \times 10^{-31} \text{ kg}$	ampere	A	10^{-3}	milli	m
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19} \text{ C}$	kelvin	K	10^{-6}	micro	μ
Avogadro's number,	$N_0 = 6.02 \times 10^{23} \text{ mol}^{-1}$	mole	mol	10^{-9}	nano	n
Universal gas constant,	$R = 8.31 \text{ J}/(\text{mol} \cdot \text{K})$	hertz	Hz	10^{-12}	pico	p
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23} \text{ J/K}$	newton	N	VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES		
Speed of light,	$c = 3.00 \times 10^8 \text{ m/s}$	pascal	Pa			
Planck's constant,	$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$	joule	J	θ	$\sin \theta$	$\cos \theta$
	$hc = 1.99 \times 10^{-25} \text{ J} \cdot \text{m}$	watt	W	0°	0	1
	$= 1.24 \times 10^3 \text{ eV} \cdot \text{nm}$	coulomb	C	30°	1/2	$\sqrt{3}/2$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2$	volt	V	45°	$\sqrt{2}/2$	$\sqrt{2}/2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$	ohm	Ω	53°	4/5	3/5
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7} (\text{T} \cdot \text{m})/\text{A}$	henry	H	60°	$\sqrt{3}/2$	1/2
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7} (\text{T} \cdot \text{m})/\text{A}$	farad	F	90°	1	0
Universal gravitational constant,	$G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg} \cdot \text{s}^2$	tesla	T			∞
Acceleration due to gravity at the Earth's surface,	$g = 9.8 \text{ m/s}^2$	degree	$^\circ$			
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^5 \text{ N/m}^2$	Celsius	$^\circ\text{C}$			
	$= 1.0 \times 10^5 \text{ Pa}$	electron-volt	eV			
1 electron volt,	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$					

The following conventions are used in this examination.

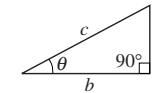
- I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.
- II. The direction of any electric current is the direction of flow of positive charge (conventional current).
- III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

ADVANCED PLACEMENT PHYSICS C EQUATIONS FOR 2004 and 2005

MECHANICS	ELECTRICITY AND MAGNETISM
$v = v_0 + at$ $x = x_0 + v_0t + \frac{1}{2}at^2$ $v^2 = v_0^2 + 2a(x - x_0)$ $\Sigma \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$ $\mathbf{F} = \frac{d\mathbf{p}}{dt}$ $\mathbf{J} = \int \mathbf{F} dt = \Delta \mathbf{p}$ $\mathbf{p} = m\mathbf{v}$ $F_{fric} \leq \mu N$ $W = \int \mathbf{F} \cdot d\mathbf{r}$ $K = \frac{1}{2}mv^2$ $P = \frac{dW}{dt}$ $P = \mathbf{F} \cdot \mathbf{v}$ $\Delta U_g = mgh$ $a_c = \frac{v^2}{r} = \omega^2 r$ $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$ $\Sigma \boldsymbol{\tau} = \boldsymbol{\tau}_{net} = I\boldsymbol{\alpha}$ $I = \int r^2 dm = \Sigma mr^2$ $\mathbf{r}_{cm} = \Sigma m\mathbf{r} / \Sigma m$ $v = r\omega$ $\mathbf{L} = \mathbf{r} \times \mathbf{p} = I\boldsymbol{\omega}$ $K = \frac{1}{2}I\omega^2$ $\omega = \omega_0 + \alpha t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$ $\mathbf{F}_s = -k\mathbf{x}$ $U_s = \frac{1}{2}kx^2$ $T = \frac{2\pi}{\omega} = \frac{1}{f}$ $T_s = 2\pi\sqrt{\frac{m}{k}}$ $T_p = 2\pi\sqrt{\frac{\ell}{g}}$ $\mathbf{F}_G = -\frac{Gm_1m_2}{r^2}\hat{\mathbf{r}}$ $U_G = -\frac{Gm_1m_2}{r}$	$F = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r^2}$ $\mathbf{E} = \frac{\mathbf{F}}{q}$ $\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$ $E = -\frac{dV}{dr}$ $V = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i}$ $U_E = qV = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r}$ $C = \frac{Q}{V}$ $C = \frac{\kappa\epsilon_0 A}{d}$ $C_p = \sum_i C_i$ $\frac{1}{C_s} = \sum_i \frac{1}{C_i}$ $I = \frac{dQ}{dt}$ $U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$ $R = \frac{\rho\ell}{A}$ $V = IR$ $R_s = \sum_i R_i$ $\frac{1}{R_p} = \sum_i \frac{1}{R_i}$ $P = IV$ $\mathbf{F}_M = q\mathbf{v} \times \mathbf{B}$ $\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I$ $\mathbf{F} = \int I d\boldsymbol{\ell} \times \mathbf{B}$ $B_s = \mu_0 nI$ $\phi_m = \int \mathbf{B} \cdot d\mathbf{A}$ $\mathcal{E} = -\frac{d\phi_m}{dt}$ $\mathcal{E} = -L\frac{dI}{dt}$ $U_L = \frac{1}{2}LI^2$

ADVANCED PLACEMENT PHYSICS C EQUATIONS FOR 2004 and 2005

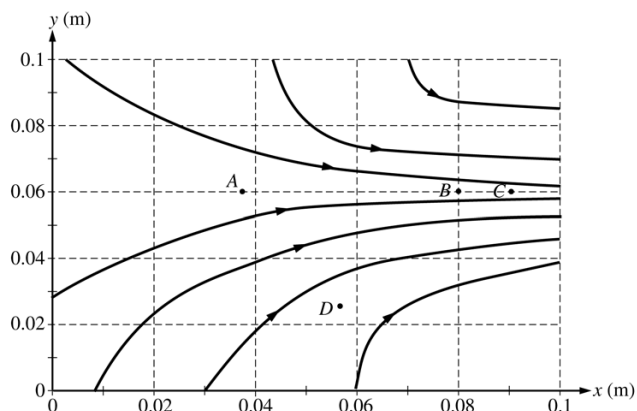
GEOMETRY AND TRIGONOMETRY	CALCULUS
Rectangle $A = bh$ Triangle $A = \frac{1}{2}bh$ Circle $A = \pi r^2$ $C = 2\pi r$ Parallelepiped $V = \ell wh$ Cylinder $V = \pi r^2 \ell$ $S = 2\pi r\ell + 2\pi r^2$ Sphere $V = \frac{4}{3}\pi r^3$ $S = 4\pi r^2$ Right Triangle $a^2 + b^2 = c^2$ $\sin \theta = \frac{a}{c}$ $\cos \theta = \frac{b}{c}$ $\tan \theta = \frac{a}{b}$	$A = \text{area}$ $C = \text{circumference}$ $V = \text{volume}$ $S = \text{surface area}$ $b = \text{base}$ $h = \text{height}$ $\ell = \text{length}$ $w = \text{width}$ $r = \text{radius}$ $\frac{df}{dx} = \frac{df}{du} \frac{du}{dx}$ $\frac{d}{dx}(x^n) = nx^{n-1}$ $\frac{d}{dx}(e^x) = e^x$ $\frac{d}{dx}(\ln x) = \frac{1}{x}$ $\frac{d}{dx}(\sin x) = \cos x$ $\frac{d}{dx}(\cos x) = -\sin x$ $\int x^n dx = \frac{1}{n+1}x^{n+1}, n \neq -1$ $\int e^x dx = e^x$ $\int \frac{dx}{x} = \ln x$ $\int \cos x dx = \sin x$ $\int \sin x dx = -\cos x$



**2005 AP[®] PHYSICS C: ELECTRICITY AND MAGNETISM
FREE-RESPONSE QUESTIONS**

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 the pink booklet in the spaces provided after each part, NOT in this green insert.

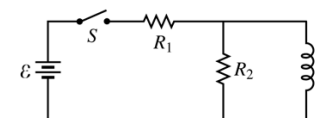


E&M. 1.

Consider the electric field diagram above.

- Points A , B , and C are all located at $y = 0.06$ m.
 - At which of these three points is the magnitude of the electric field the greatest? Justify your answer.
 - At which of these three points is the electric potential the greatest? Justify your answer.
- An electron is released from rest at point B .
 - Qualitatively describe the electron's motion in terms of direction, speed, and acceleration.
 - Calculate the electron's speed after it has moved through a potential difference of 10 V.
- 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.
- On the diagram, draw an equipotential line that passes through point D and intersects at least three electric field lines.

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FREE-RESPONSE QUESTIONS**



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.

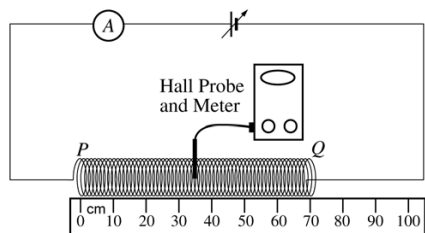
- Determine the current through resistor 1 immediately after the switch is closed.
- Determine the magnitude of the initial rate of change of current, dI/dt , in the inductor.
- Determine the current through the battery a long time after the switch has been closed.
- On the axes below, sketch a graph of the current through the battery as a function of time.



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

- Determine the voltage across resistor 2 just after the switch has been opened.

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FREE-RESPONSE QUESTIONS**



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.

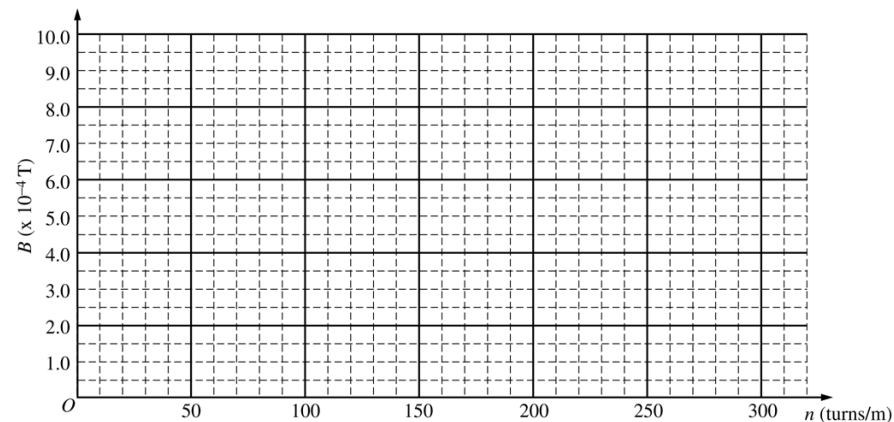
Trial	Position of End Q (cm)	Measured Magnetic Field (T) (directed from P to Q)	n (turns/m)
1	40	9.70×10^{-4}	
2	50	7.70×10^{-4}	
3	60	6.80×10^{-4}	
4	80	4.90×10^{-4}	
5	100	4.00×10^{-4}	

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

*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.

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

END OF SECTION II, ELECTRICITY AND MAGNETISM