



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,	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$ $= 931 \text{ MeV}/c^2$	meter	m	10^9	giga	G	
Proton mass,	$m_p = 1.67 \times 10^{-27} \text{ kg}$	kilogram	kg	10^6	mega	M	
Neutron mass,	$m_n = 1.67 \times 10^{-27} \text{ kg}$	second	s	10^3	kilo	k	
Electron mass,	$m_e = 9.11 \times 10^{-31} \text{ kg}$	ampere	A	10^{-2}	centi	c	
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19} \text{ C}$	kelvin	K	10^{-3}	milli	m	
Avogadro's number,	$N_0 = 6.02 \times 10^{23} \text{ mol}^{-1}$	mole	mol	10^{-6}	micro	μ	
Universal gas constant,	$R = 8.31 \text{ J}/(\text{mol} \cdot \text{K})$	hertz	Hz	10^{-9}	nano	n	
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23} \text{ J/K}$	newton	N	10^{-12}	pico	p	
Speed of light,	$c = 3.00 \times 10^8 \text{ m/s}$	pascal	Pa	VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES			
Planck's constant,	$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$ $= 4.14 \times 10^{-15} \text{ eV} \cdot \text{s}$	joule	J				
	$hc = 1.99 \times 10^{-25} \text{ J} \cdot \text{m}$ $= 1.24 \times 10^3 \text{ eV} \cdot \text{nm}$	watt	W	θ	$\sin \theta$	$\cos \theta$	$\tan \theta$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2$	coulomb	C	0°	0	1	0
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$	volt	V	30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7} (\text{T} \cdot \text{m})/\text{A}$	ohm	Ω	37°	3/5	4/5	3/4
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7} (\text{T} \cdot \text{m})/\text{A}$	henry	H	45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
Universal gravitational constant,	$G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg} \cdot \text{s}^2$	farad	F	53°	4/5	3/5	4/3
Acceleration due to gravity at the Earth's surface,	$g = 9.8 \text{ m/s}^2$	tesla	T	60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^5 \text{ N/m}^2$ $= 1.0 \times 10^5 \text{ Pa}$	degree Celsius	$^\circ\text{C}$	90°	1	0	∞
1 electron volt,	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	electron-volt	eV				

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

$v = v_0 + at$	$a = \text{acceleration}$
$x = x_0 + v_0t + \frac{1}{2}at^2$	$F = \text{force}$
$v^2 = v_0^2 + 2a(x - x_0)$	$f = \text{frequency}$
$\Sigma \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$	$h = \text{height}$
$\mathbf{F} = \frac{d\mathbf{p}}{dt}$	$I = \text{rotational inertia}$
$\mathbf{J} = \int \mathbf{F} dt = \Delta \mathbf{p}$	$J = \text{impulse}$
$\mathbf{p} = m\mathbf{v}$	$K = \text{kinetic energy}$
$F_{fric} \leq \mu N$	$k = \text{spring constant}$
$W = \int \mathbf{F} \cdot d\mathbf{r}$	$\ell = \text{length}$
$K = \frac{1}{2}mv^2$	$L = \text{angular momentum}$
$P = \frac{dW}{dt}$	$m = \text{mass}$
$P = \mathbf{F} \cdot \mathbf{v}$	$N = \text{normal force}$
$\Delta U_g = mgh$	$P = \text{power}$
$a_c = \frac{v^2}{r} = \omega^2 r$	$p = \text{momentum}$
$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$	$r = \text{radius or distance}$
$\Sigma \boldsymbol{\tau} = \boldsymbol{\tau}_{net} = I\boldsymbol{\alpha}$	$\mathbf{r} = \text{position vector}$
$I = \int r^2 dm = \Sigma mr^2$	$T = \text{period}$
$\mathbf{r}_{cm} = \Sigma m\mathbf{r} / \Sigma m$	$t = \text{time}$
$v = r\omega$	$U = \text{potential energy}$
$\mathbf{L} = \mathbf{r} \times \mathbf{p} = I\boldsymbol{\omega}$	$v = \text{velocity or speed}$
$K = \frac{1}{2}I\omega^2$	$W = \text{work done on a system}$
$\omega = \omega_0 + \alpha t$	$x = \text{position}$
$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$	$\mu = \text{coefficient of friction}$
$\mathbf{F}_s = -k\mathbf{x}$	$\theta = \text{angle}$
$U_s = \frac{1}{2}kx^2$	$\tau = \text{torque}$
$T = \frac{2\pi}{\omega} = \frac{1}{f}$	$\omega = \text{angular speed}$
$T_s = 2\pi\sqrt{\frac{m}{k}}$	$\alpha = \text{angular acceleration}$
$T_p = 2\pi\sqrt{\frac{\ell}{g}}$	
$\mathbf{F}_G = -\frac{Gm_1m_2}{r^2}\hat{\mathbf{r}}$	
$U_G = -\frac{Gm_1m_2}{r}$	

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r^2}$	$A = \text{area}$
$\mathbf{E} = \frac{\mathbf{F}}{q}$	$B = \text{magnetic field}$
$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$	$C = \text{capacitance}$
$E = -\frac{dV}{dr}$	$d = \text{distance}$
$V = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i}$	$E = \text{electric field}$
$U_E = qV = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r}$	$\mathcal{E} = \text{emf}$
$C = \frac{Q}{V}$	$F = \text{force}$
$C = \frac{\kappa\epsilon_0 A}{d}$	$I = \text{current}$
$C_p = \sum_i C_i$	$L = \text{inductance}$
$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$	$\ell = \text{length}$
$I = \frac{dQ}{dt}$	$n = \text{number of loops of wire per unit length}$
$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$	$P = \text{power}$
$R = \frac{\rho\ell}{A}$	$Q = \text{charge}$
$V = IR$	$q = \text{point charge}$
$R_s = \sum_i R_i$	$R = \text{resistance}$
$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$	$r = \text{distance}$
$P = IV$	$t = \text{time}$
$\mathbf{F}_M = q\mathbf{v} \times \mathbf{B}$	$U = \text{potential or stored energy}$
$\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I$	$V = \text{electric potential}$
$\mathbf{F} = \int I d\boldsymbol{\ell} \times \mathbf{B}$	$v = \text{velocity or speed}$
$B_s = \mu_0 nI$	$\rho = \text{resistivity}$
$\phi_m = \int \mathbf{B} \cdot d\mathbf{A}$	$\phi_m = \text{magnetic flux}$
$\mathcal{E} = -\frac{d\phi_m}{dt}$	$\kappa = \text{dielectric constant}$
$\mathcal{E} = -L\frac{dI}{dt}$	
$U_L = \frac{1}{2}LI^2$	

ADVANCED PLACEMENT PHYSICS C EQUATIONS FOR 2004 and 2005

GEOMETRY AND TRIGONOMETRY

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

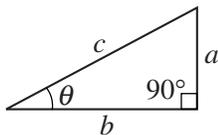
$$a^2 + b^2 = c^2$$

$$\sin \theta = \frac{a}{c}$$

$$\cos \theta = \frac{b}{c}$$

$$\tan \theta = \frac{a}{b}$$

A = area
 C = circumference
 V = volume
 S = surface area
 b = base
 h = height
 ℓ = length
 w = width
 r = radius



CALCULUS

$$\frac{df}{dx} = \frac{df}{du} \frac{du}{dx}$$

$$\frac{d}{dx}(x^n) = nx^{n-1}$$

$$\frac{d}{dx}(e^x) = e^x$$

$$\frac{d}{dx}(\ln x) = \frac{1}{x}$$

$$\frac{d}{dx}(\sin x) = \cos x$$

$$\frac{d}{dx}(\cos x) = -\sin x$$

$$\int x^n dx = \frac{1}{n+1}x^{n+1}, n \neq -1$$

$$\int e^x dx = e^x$$

$$\int \frac{dx}{x} = \ln|x|$$

$$\int \cos x dx = \sin x$$

$$\int \sin x dx = -\cos x$$

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

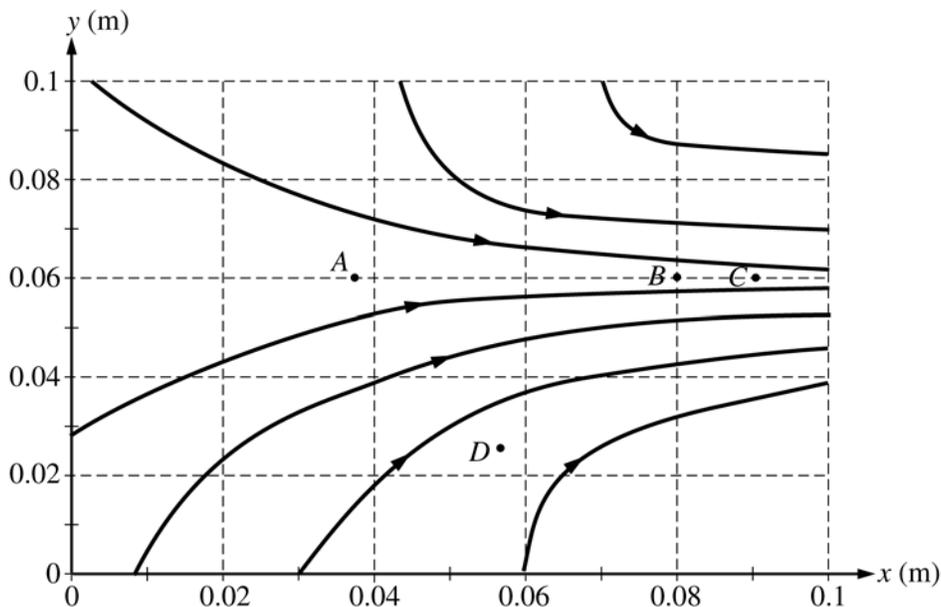
PHYSICS C

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.

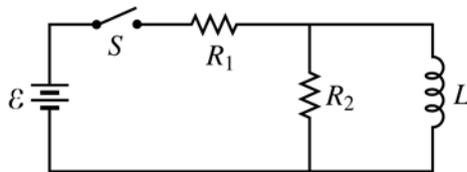


E&M. 1.

Consider the electric field diagram above.

- (a) 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.
- (b) 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.
- (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.
- (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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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.

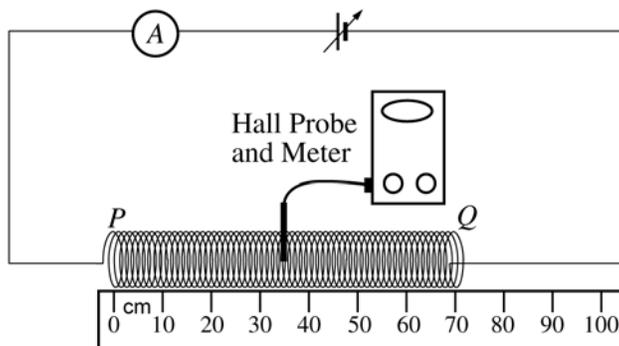
- Determine the current through resistor 1 immediately after the switch is closed.
- Determine the magnitude of the initial rate of change of current, dI/dt , in the inductor.
- Determine the current through the battery a long time after the switch has been closed.
- On the axes below, sketch a graph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

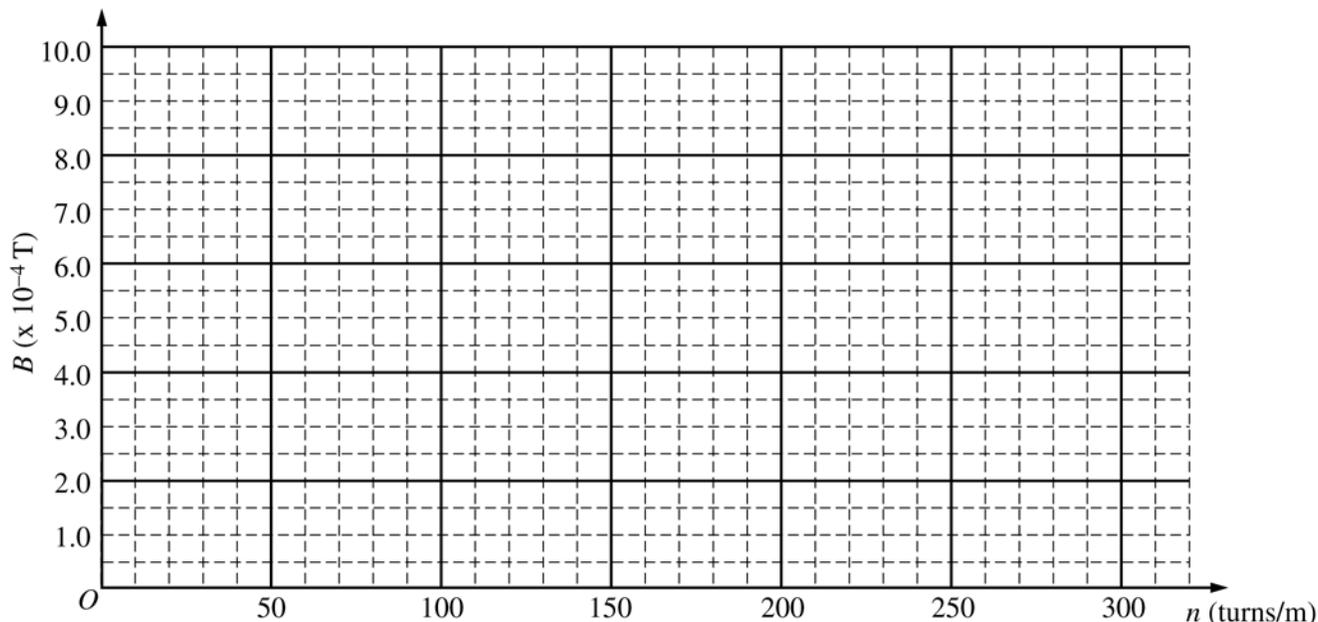
Trial	Position of End Q (cm)	Measured Magnetic Field (T) (directed from P to Q)	n (turns/m)
1	40	9.70×10^{-4}	
2	50	7.70×10^{-4}	
3	60	6.80×10^{-4}	
4	80	4.90×10^{-4}	
5	100	4.00×10^{-4}	

(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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FREE-RESPONSE QUESTIONS

- (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