FORM 3PBP

The College Board
Advanced Placement Examination
PHYSICS C
SECTION II

1993

TABLE OF INFORMATION

1 atomic mass unit,	$1\ \text{u} = 1.66 \times 10^{-27}$ kilogram
Rest mass of the proton,	$m_p = 1.67 \times 10^{-27}$ kilogram
Rest mass of the neutron,	$m_n = 1.67 \times 10^{-27}$ kilogram
Rest mass of the electron,	$m_e = 9.11 \times 10^{-31}$ kilogram
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19}$ coulomb
Avogadro's number,	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant,	$R = 8.32$ joules/(mole · K)
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ joule/K
Speed of light,	$c = 3.00 \times 10^{8}$ meters/second
Planck's constant,	$h = 6.63 \times 10^{-34}$ joule · second $= 4.14 \times 10^{-15}$ eV · second
	$hc = 1.99 \times 10^{-25}$ joule · meter $= 1240$ eV · nanometers
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}$ joule
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb^2/(newton · meter^2)
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ newtons · meter^2/coulomb^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Magnetic constant,	$k' = k/c^2 = \mu_0/4\pi = 10^{-7}$ weber/(ampere · meter)
Acceleration due to gravity at the Earth's surface,	$g = 9.8$ meters/second^2
Universal gravitational constant,	$G = 6.67 \times 10^{-11}$ meter^3/(kilogram · second^2)
1 atmosphere pressure,	$1\ \text{atm} = 1.0 \times 10^{5}$ newtons/meter^2 $= 1.0 \times 10^{5}$ pascals (Pa)
1 angstrom,	$1\ \text{Å} = 1 \times 10^{-10}$ meter
1 tesla,	$1\ \text{T} = 1$ weber/meter^2

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.

This insert may be used for reference and /or scratchwork as you answer the free-response questions, but be sure to show all your work on problems and write your answers in the pink booklet. No credit will be given for work shown on this green insert.

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PHYSICS C

SECTION II, MECHANICS

Time— 45 minutes

3 Questions

ANSWER ALL OF THE QUESTIONS. EACH OF THE THREE QUESTIONS HAS EQUAL WEIGHT, BUT THE PARTS WITHIN A QUESTION MAY NOT HAVE EQUAL WEIGHT. SHOW YOUR WORK. CREDIT FOR YOUR ANSWERS DEPENDS ON THE QUALITY OF YOUR EXPLANATIONS.

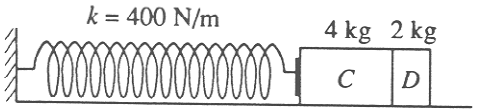

Figure I

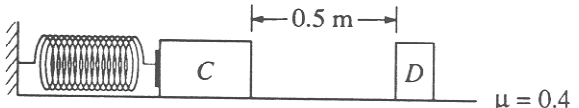

Figure II

Mech. 1. A massless spring with force constant $k = 400$ newtons per meter is fastened at its left end to a vertical wall, as shown in Figure I. Initially, block C (mass $m_C = 4.0$ kilograms) and block D (mass $m_D = 2.0$ kilograms) rest on a horizontal surface with block C in contact with the spring (but not compressing it) and with block D in contact with block C. Block C is then moved to the left, compressing the spring a distance of 0.50 meter, and held in place while block D remains at rest as shown in Figure II. (Use $g = 10$ m/s^2.)

(a) Determine the elastic energy stored in the compressed spring.

Block C is then released and accelerates to the right, toward block D. The surface is rough and the coefficient of friction between each block and the surface is $\mu = 0.4$. The two blocks collide instantaneously, stick together, and move to the right. Remember that the spring is not attached to block C. Determine each of the following.

(b) The speed v_C of block C just before it collides with block D

(c) The speed v_f of blocks C and D just after they collide

(d) The horizontal distance the blocks move before coming to rest

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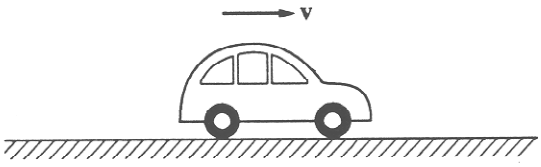

Mech. 2. A car of mass m, initially at rest at time $t = 0$, is driven to the right, as shown above, along a straight, horizontal road with the engine causing a constant force $\mathbf{F_0}$ to be applied. While moving, the car encounters a resistance force equal to $-k\mathbf{v}$, where $\mathbf{v}$ is the velocity of the car and k is a positive constant.

(a) The dot below represents the center of mass of the car. On this figure, draw and label vectors to represent all the forces acting on the car as it moves with a velocity $\mathbf{v}$ to the right.

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(b) Determine the horizontal acceleration of the car in terms of k, v, F_0, and m.

(c) Derive the equation expressing the velocity of the car as a function of time t in terms of k, F_0, and m.

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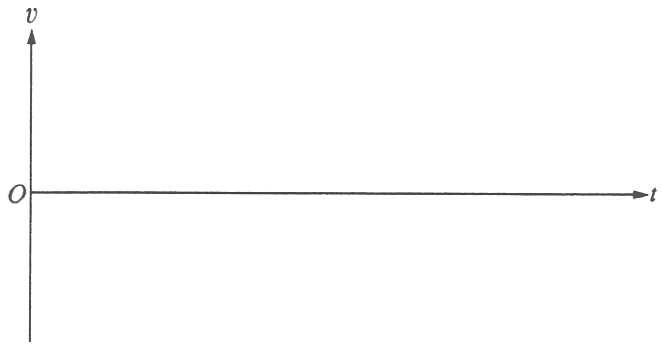
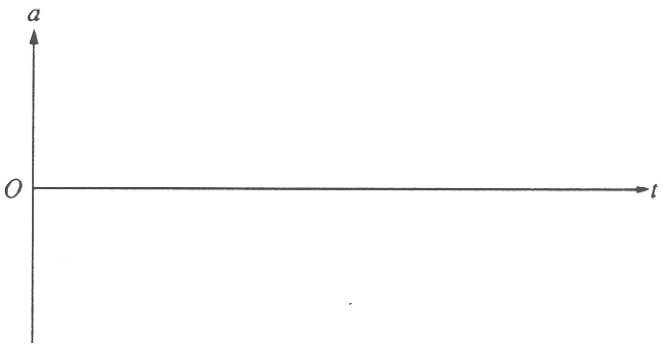
(d) On the axes below, sketch a graph of the car's velocity v as a function of time t. Label important values on the vertical axis.



(e) On the axes below, sketch a graph of the car's acceleration a as a function of time t. Label important values on the vertical axis.



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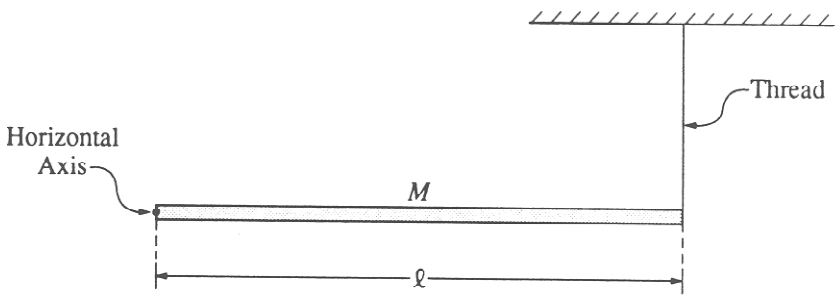


Mech. 3. A long, uniform rod of mass M and length ℓ is supported at the left end by a horizontal axis into the page and perpendicular to the rod, as shown above. The right end is connected to the ceiling by a thin vertical thread so that the rod is horizontal. The moment of inertia of the rod about the axis at the end of the rod is $M\ell^2/3$. Express the answers to all parts of this question in terms of M, ℓ, and g.

(a) Determine the magnitude and direction of the force exerted on the rod by the axis.

The thread is then burned by a match. For the time immediately after the thread breaks, determine each of the following.

(b) The angular acceleration of the rod about the axis

(c) The translational acceleration of the center of mass of the rod

(d) The force exerted on the end of the rod by the axis

The rod rotates about the axis and swings down from the horizontal position.

(e) Determine the angular velocity of the rod as a function of θ, the arbitrary angle through which the rod has swung.

STOP

END OF SECTION II, MECHANICS

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON SECTION II, MECHANICS, ONLY. DO NOT TURN TO ANY OTHER TEST MATERIALS.

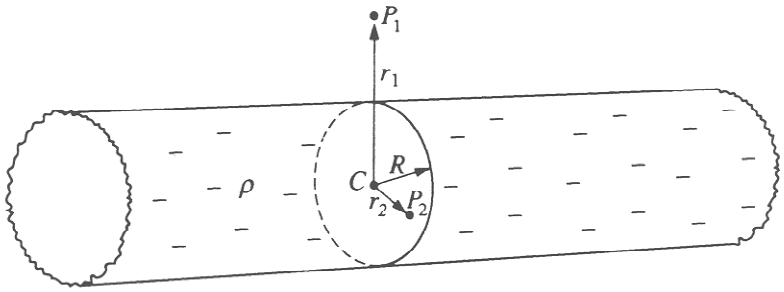
PHYSICS C

SECTION II, ELECTRICITY AND MAGNETISM

Time—45 minutes

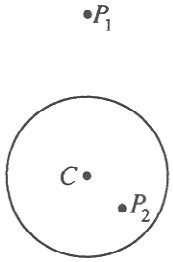
3 Questions

ANSWER ALL OF THE QUESTIONS. EACH OF THE THREE QUESTIONS HAS EQUAL WEIGHT, BUT THE PARTS WITHIN A QUESTION MAY NOT HAVE EQUAL WEIGHT. SHOW YOUR WORK. CREDIT FOR YOUR ANSWERS DEPENDS ON THE QUALITY OF YOUR EXPLANATIONS.



E & M 1. The solid nonconducting cylinder of radius R shown above is very long. It contains a negative charge evenly distributed throughout the cylinder, with volume charge density ρ. Point P_1 is outside the cylinder at a distance r_1 from its center C and point P_2 is inside the cylinder at a distance r_2 from its center C. Both points are in the same plane, which is perpendicular to the axis of the cylinder.

(a) On the following cross-sectional diagram, draw vectors to indicate the directions of the electric field at points P_1 and P_2.



(b) Using Gauss's law, derive expressions for the magnitude of the electric field E in terms of r, R, ρ, and fundamental constants for the following two cases.

i. $r > R$ (outside the cylinder)
ii. $r < R$ (inside the cylinder)

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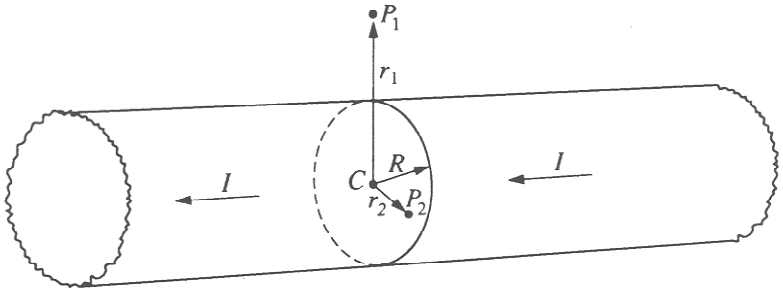
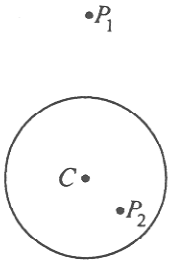


Another cylinder of the same dimensions, but made of conducting material, carries a total current I parallel to the length of the cylinder, as shown in the diagram above. The current density is uniform throughout the cross-sectional area of the cylinder. Points P_1 and P_2 are in the same positions with respect to the cylinder as they were for the nonconducting cylinder.

(c) On the following cross-sectional diagram in which the current is out of the plane of the page (toward the reader), draw vectors to indicate the directions of the magnetic field at points P_1 and P_2.



(d) Use Ampère's law to derive an expression for the magnetic field B inside the cylinder in terms of r, R, I, and fundamental constants.

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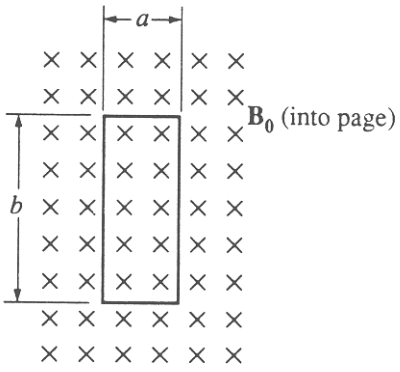


E & M 2. A rectangular loop of copper wire of resistance R has width a and length b. The loop is stationary in a constant, uniform magnetic field $\mathbf{B}_0$, directed into the page as shown above.

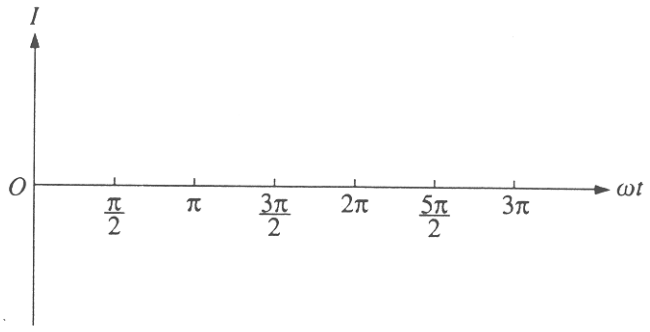
(a) i. What is the net magnetic flux through the loop of wire?
ii. What is the induced emf in the loop of wire?
iii. What is the net magnetic force on the loop of wire?

Suppose instead that the uniform magnetic field varies with time t according to the relationship $B = B_0 \cos \omega t$, where ω and B_0 are positive constants and B is positive when the field is directed into the page.

(b) Indicate on the diagram below the direction of the induced current in the loop when $\omega t = \pi/2$, after the magnetic field begins to oscillate.

(c) i. Derive the expression for the magnitude of the induced current in the loop as a function of time in terms of a, b, B_0, ω, R, t, and fundamental constants.

ii. On the axes below, sketch a graph of the induced current I versus ωt, taking clockwise current to be positive.



iii. State explicitly the maximum value of the current I.

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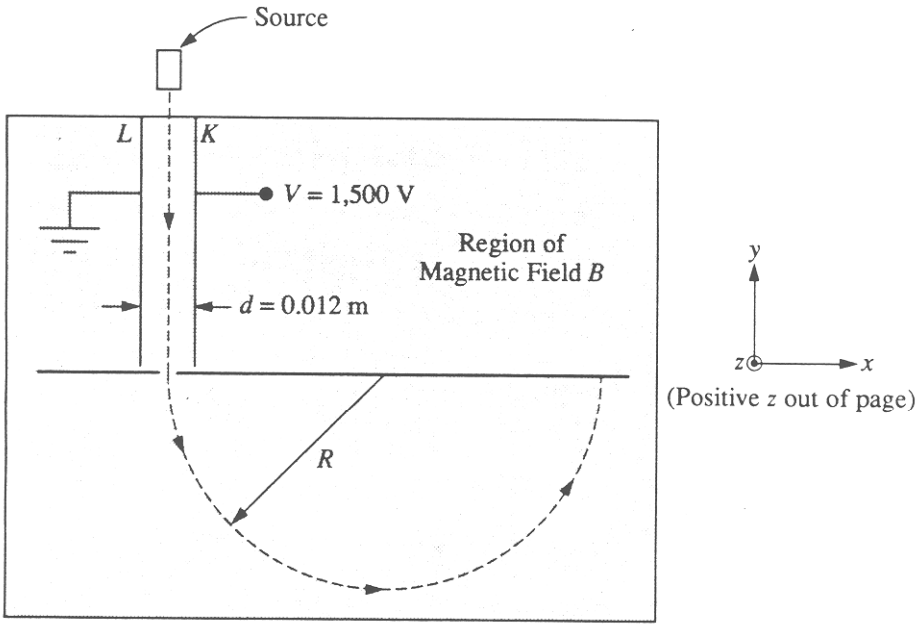

E & M 3. A mass spectrometer, constructed as shown in the diagram above, is to be used for determining the mass of singly ionized positively charged ions. There is a uniform magnetic field $B = 0.20$ tesla perpendicular to the page in the shaded region of the diagram. A potential difference $V = 1{,}500$ volts is applied across the parallel plates L and K, which are separated by a distance $d = 0.012$ meter and which act as a velocity selector.

(a) In which direction, relative to the coordinate system shown above on the right, should the magnetic field point in order for positive ions to move along the path shown by the dashed line in the diagram above?

(b) Should plate K have a positive or negative voltage polarity with respect to plate L?

(c) Calculate the magnitude of the electric field between the plates.

(d) Calculate the speed of a particle that can pass between the parallel plates without being deflected.

(e) Calculate the mass of a hypothetical singly charged ion that travels in a semicircle of radius $R = 0.50$ meter.

(f) A doubly ionized positive ion of the same mass and velocity as the singly charged ion enters the mass spectrometer. What is the radius of its path?

STOP

END OF SECTION II, ELECTRICITY AND MAGNETISM

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON SECTION II, ELECTRICITY AND MAGNETISM, ONLY. DO NOT TURN TO ANY OTHER TEST MATERIALS.

NO TEST MATERIAL ON THIS PAGE