Student Name ____________

Teacher Name HUEBNER

School MANALAPAN H.S.

The College Board AP ADVANCED PLACEMENT PROGRAM

2002

Physics C

SECTION II

TABLE OF INFORMATION FOR 2002

CONSTANTS AND CONVERSION FACTORS

1 unified atomic mass unit,	$1\ \text{u} = 1.66 \times 10^{-27}$ kg
	$= 931\ \text{MeV}/c^2$
Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19}$ C
Avogadro's number,	$N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$
Universal gas constant,	$R = 8.31\ \text{J}/(\text{mol} \cdot \text{K})$
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ J/K
Speed of light,	$c = 3.00 \times 10^8$ m/s
Planck's constant,	$h = 6.63 \times 10^{-34}\ \text{J} \cdot \text{s}$
	$= 4.14 \times 10^{-15}\ \text{eV} \cdot \text{s}$
	$hc = 1.99 \times 10^{-25}\ \text{J} \cdot \text{m}$
	$= 1.24 \times 10^3\ \text{eV} \cdot \text{nm}$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N} \cdot \text{m}^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}(\text{T} \cdot \text{m})/\text{A}$
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}(\text{T} \cdot \text{m})/\text{A}$
Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg} \cdot \text{s}^2$
Acceleration due to gravity at the Earth's surface,	$g = 9.8\ \text{m/s}^2$
1 atmosphere pressure,	$1\ \text{atm} = 1.0 \times 10^5\ \text{N/m}^2$
	$= 1.0 \times 10^5$ Pa
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}$ J

UNITS

Name	Symbol
meter	m
kilogram	kg
second	s
ampere	A
kelvin	K
mole	mol
hertz	Hz
newton	N
pascal	Pa
joule	J
watt	W
coulomb	C
volt	V
ohm	Ω
henry	H
farad	F
tesla	T
degree Celsius	°C
electron-volt	eV

PREFIXES

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	sin θ	cos θ	tan θ
0°	0	1	0
30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
37°	3/5	4/5	3/4
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
53°	4/5	3/5	4/3
60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
90°	1	0	∞

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.

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ADVANCED PLACEMENT PHYSICS C EQUATIONS FOR 2002

MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2} at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$\mathbf{F} = \frac{d\mathbf{p}}{dt}$

$\mathbf{J} = \int \mathbf{F}\, dt = \Delta \mathbf{p}$

$\mathbf{p} = m\mathbf{v}$

$F_{fric} \le \mu N$

$W = \int \mathbf{F} \cdot d\mathbf{r}$

$K = \frac{1}{2} mv^2$

$P = \frac{dW}{dt}$

$P = \mathbf{F} \cdot \mathbf{v}$

$\Delta U_g = mgh$

$a_c = \frac{v^2}{r} = \omega^2 r$

$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$

$\sum \boldsymbol{\tau} = \boldsymbol{\tau}_{net} = I\boldsymbol{\alpha}$

$I = \int r^2 dm = \sum mr^2$

$\mathbf{r}_{cm} = \sum m\mathbf{r} / \sum m$

$v = r\omega$

$\mathbf{L} = \mathbf{r} \times \mathbf{p} = I\boldsymbol{\omega}$

$K = \frac{1}{2} I\omega^2$

$\omega = \omega_0 + \alpha t$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$

$\mathbf{F}_s = -k\mathbf{x}$

$U_s = \frac{1}{2} kx^2$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$\mathbf{F}_G = -\frac{Gm_1 m_2}{r^2}\,\hat{\mathbf{r}}$

$U_G = -\frac{Gm_1 m_2}{r}$

- a = acceleration
- F = force
- f = frequency
- h = height
- I = rotational inertia
- J = impulse
- K = kinetic energy
- k = spring constant
- ℓ = length
- L = angular momentum
- m = mass
- N = normal force
- P = power
- p = momentum
- r = radius or distance
- $\mathbf{r}$ = position vector
- T = period
- t = time
- U = potential energy
- v = velocity or speed
- W = work done on a system
- x = position
- μ = coefficient of friction
- θ = angle
- τ = torque
- ω = angular speed
- α = angular acceleration

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$

$E = -\frac{dV}{dr}$

$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$

$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$

$C = \frac{Q}{V}$

$C = \frac{\kappa\epsilon_0 A}{d}$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$I = \frac{dQ}{dt}$

$U_c = \frac{1}{2} QV = \frac{1}{2} CV^2$

$R = \frac{\rho\ell}{A}$

$V = IR$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$P = IV$

$\mathbf{F}_M = q\mathbf{v} \times \mathbf{B}$

$\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I$

$\mathbf{F} = \int I\, d\boldsymbol{\ell} \times \mathbf{B}$

$B_s = \mu_0 n I$

$\phi_m = \int \mathbf{B} \cdot d\mathbf{A}$

$\mathcal{E} = -\frac{d\phi_m}{dt}$

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

$U_L = \frac{1}{2} LI^2$

- A = area
- B = magnetic field
- C = capacitance
- d = distance
- E = electric field
- $\mathcal{E}$ = emf
- F = force
- I = current
- L = inductance
- ℓ = length
- n = number of loops of wire per unit length
- P = power
- Q = charge
- q = point charge
- R = resistance
- r = distance
- t = time
- U = potential or stored energy
- V = electric potential
- v = velocity or speed
- ρ = resistivity
- ϕ_m = magnetic flux
- κ = dielectric constant

ADVANCED PLACEMENT PHYSICS C EQUATIONS FOR 2002

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

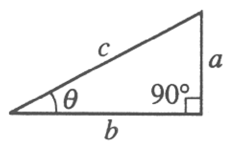
$a^2 + b^2 = c^2$

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

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

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

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



CALCULUS

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

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

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

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

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

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

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

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

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

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

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

PHYSICS C

Section II, MECHANICS

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.

Mech 1.

A crash test car of mass 1,000 kg moving at constant speed of 12 m/s collides completely inelastically with an object of mass M at time $t = 0$. The object was initially at rest. The speed v in m/s of the car-object system after the collision is given as a function of time t in seconds by the expression

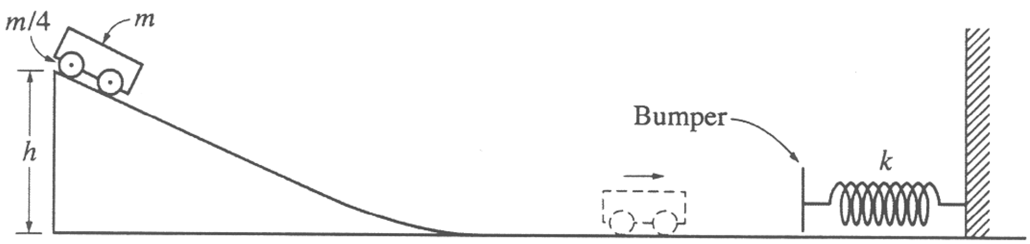
$$v = \frac{8}{1 + 5t}.$$

(a) Calculate the mass M of the object.

(b) Assuming an initial position of $x = 0$, determine an expression for the position of the car-object system after the collision as a function of time t.

(c) Determine an expression for the resisting force on the car-object system after the collision as a function of time t.

(d) Determine the impulse delivered to the car-object system from $t = 0$ to $t = 2.0$ s.



Mech 2.

The cart shown above is made of a block of mass m and four solid rubber tires each of mass $m/4$ and radius r. Each tire may be considered to be a disk. (A disk has rotational inertia $\frac{1}{2}ML^2$, where M is the mass and L is the radius of the disk.) The cart is released from rest and rolls without slipping from the top of an inclined plane of height h. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Determine the total rotational inertia of all four tires.

(b) Determine the speed of the cart when it reaches the bottom of the incline.

(c) After rolling down the incline and across the horizontal surface, the cart collides with a bumper of negligible mass attached to an ideal spring, which has a spring constant k. Determine the distance x_m the spring is compressed before the cart and bumper come to rest.

(d) Now assume that the bumper has a non-neglible mass. After the collision with the bumper, the spring is compressed to a maximum distance of about 90% of the value of x_m in part (c). Give a reasonable explanation for this decrease.

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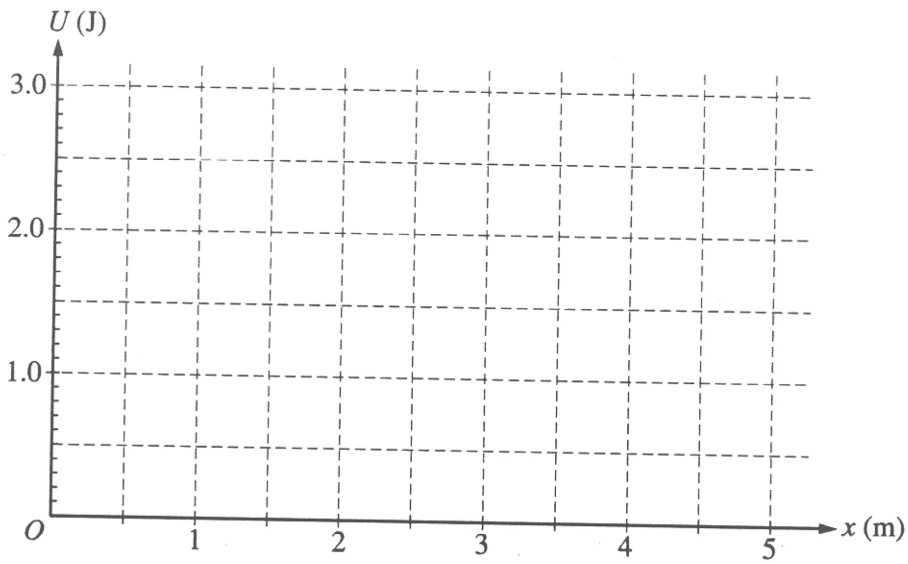
Mech 3.

An object of mass 0.5 kg experiences a force that is associated with the potential energy function $U(x) = \frac{4.0}{2.0 + x}$, where U is in joules and x is in meters.

(a) On the axes below, sketch the graph of $U(x)$ versus x.



(b) Determine the force associated with the potential energy function given above.

(c) Suppose that the object is released from rest at the origin. Determine the speed of the particle at $x = 2$ m.

In the laboratory, you are given a glider of mass 0.5 kg on an air track. The glider is acted on by the force determined in part (b). Your goal is to determine experimentally the validity of your theoretical calculation in part (c).

(d) From the list below, select the additional equipment you will need from the laboratory to do your experiment by checking the line next to each item. If you need more than one of an item, place the number you need on the line.

___ Meterstick   ___ Stopwatch   ___ Photogate timer   ___ String   ___ Spring

___ Balance   ___ Wood block   ___ Set of objects of different masses

(e) Briefly outline the procedure you will use, being explicit about what measurements you need to make in order to determine the speed. You may include a labeled diagram of your setup if it will clarify your procedure.

THIS PAGE MAY BE USED FOR SCRATCHWORK.

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.

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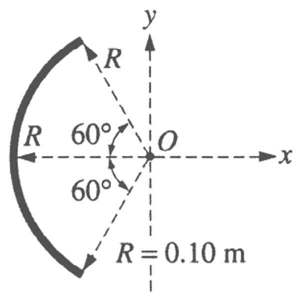
PHYSICS C

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.

A rod of uniform linear charge density $\lambda = +1.5 \times 10^{-5}$ C/m is bent into an arc of radius $R = 0.10$ m. The arc is placed with its center at the origin of the axes shown above.

(a) Determine the total charge on the rod.

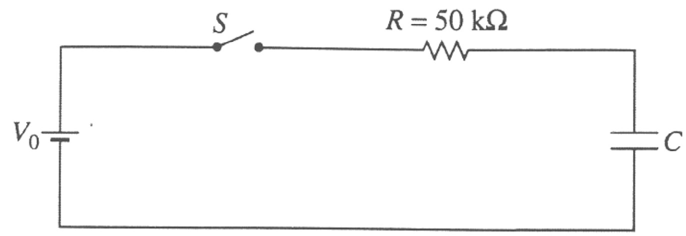
(b) Determine the magnitude and direction of the electric field at the center O of the arc.

(c) Determine the electric potential at point O.

A proton is now placed at point O and held in place. Ignore the effects of gravity in the rest of this problem.

(d) Determine the magnitude and direction of the force that must be applied in order to keep the proton at rest.

(e) The proton is now released. Describe in words its motion for a long time after its release.



E&M 2.

Your engineering firm has built the RC circuit shown above. The current is measured for the time t after the switch is closed at $t = 0$ and the best-fit curve is represented by the equation $I(t) = 5.20\, e^{-t/10}$, where I is in milliamperes and t is in seconds.

(a) Determine the value of the charging voltage V_0 predicted by the equation.

(b) Determine the value of the capacitance C predicted by the equation.

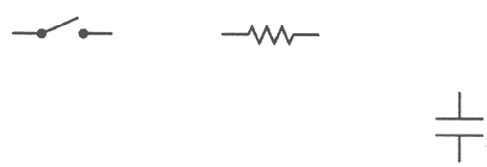
(c) The charging voltage is measured in the laboratory and found to be greater than predicted in part (a).

i. Give one possible explanation for this finding.

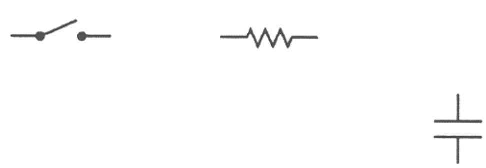
ii. Explain the implications that your answer to part i has for the predicted value of the capacitance.

(d) Your laboratory supervisor tells that you the charging time must be decreased. You may add resistors or capacitors to the original components and reconnect the RC circuit. In parts i and ii below, show how to reconnect the circuit, using either an additional resistor or a capacitor to decrease the charging time.

i. Indicate how a resistor may be added to decrease the charging time. Add the necessary resistor and connections to the following diagram.



ii. Instead of a resistor, use a capacitor. Indicate how the capacitor may be added to decrease the charging time. Add the necessary capacitor and connections to the following diagram.



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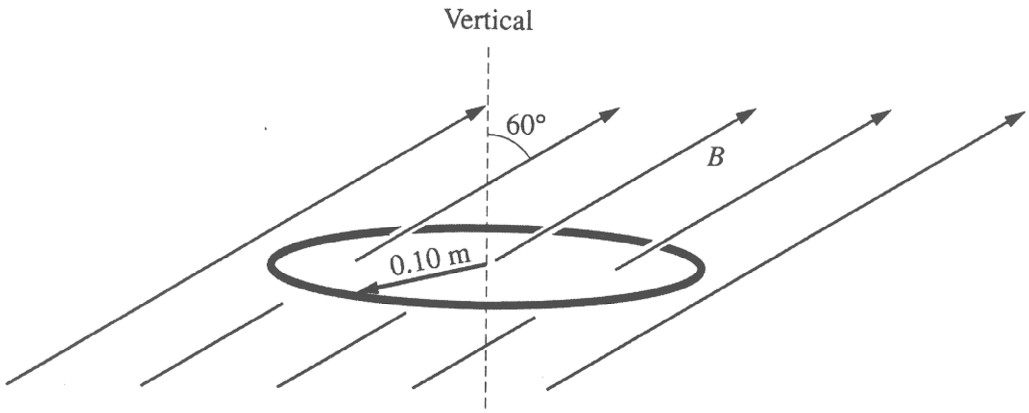
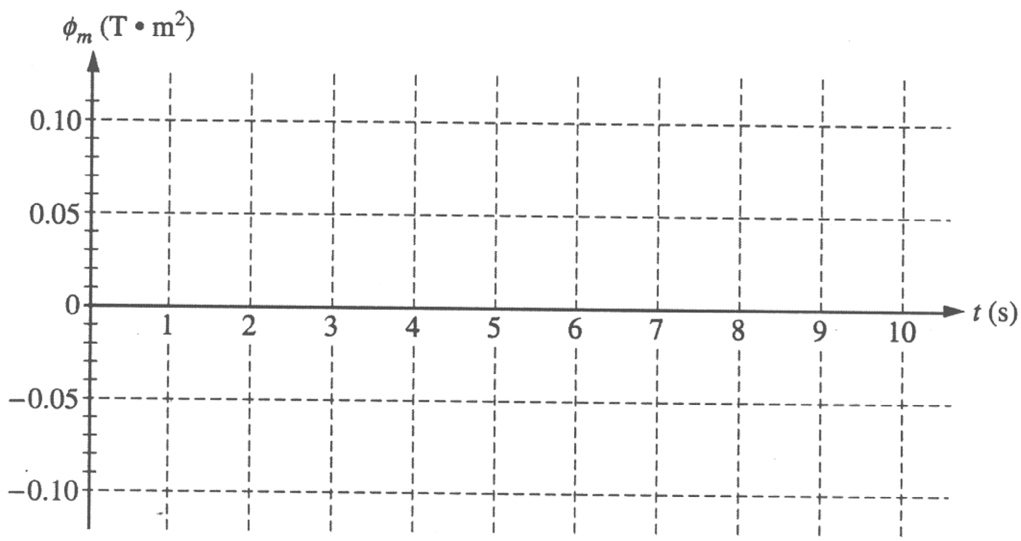


E&M 3.

A circular wire loop with radius 0.10 m and resistance 50 Ω is suspended horizontally in a magnetic field of magnitude B directed upward at an angle of 60° with the vertical, as shown above. The magnitude of the field in teslas is given as a function of time t in seconds by the equation $B = 4(1 - 0.2t)$.

(a) Determine the magnetic flux ϕ_m through the loop as a function of time.

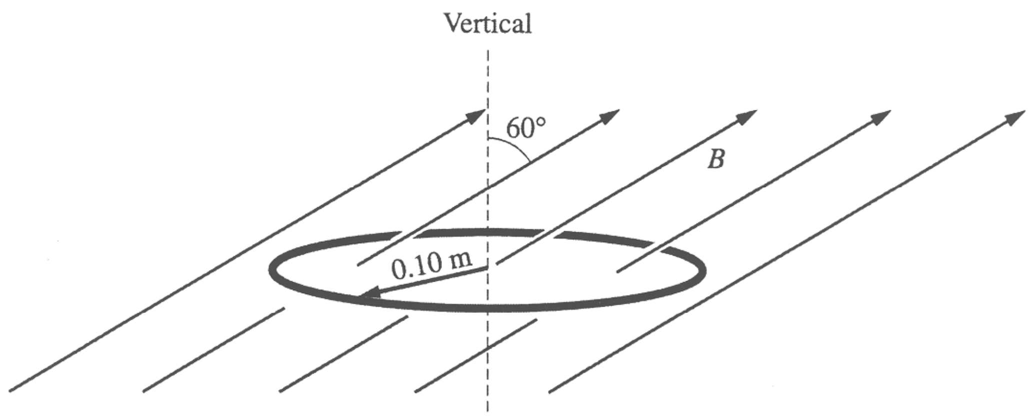
(b) Graph the magnetic flux ϕ_m as a function of time on the axes below.



(c) Determine the magnitude of the induced emf in the loop.

(d) i. Determine the magnitude of the induced current in the loop.

ii. Show the direction of the induced current on the following diagram.



(e) Determine the energy dissipated in the loop from $t = 0$ to $t = 4$ s.

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